DOCUMENT RESUME

ED 299 105 SE 049 601

TITLE	Revitalizing Nuclear Safety Research.
INSTITUTION	National Academy of Sciences - National Research Council, Washington, D.C.
SPONS AGENCY	Nuclear Regulatory Commission, Washington, D.C.
PUB DATE	86
NOTE	223p.; Contains small print which may not reproduce well.
AVAILABLE FROM	Commission on Physical Sciences, Mathematics, and Resources, 2101 Constitution Avenue, Washington, DC 20418 (limited supply).
PUB TYPE	Reports - Research/Technical (143)
EDRS PRICE	MF01/PC09 Plus Postage.
DESCRIPTORS	*Accident Prevention; College Science; Engineering; Higher Education; *Nuclear Energy; Nuclear Power Plants; Nuclear Technology; *Program Evaluation; *Safety; Science Education; *Scientific Research
IDENTIFIERS	Department of Energy; Nuclear Engineering; *Nuclear Reactors

ABSTRACT

This report covers the general issues involved in nuclear safety research and points out the areas needing detailed consideration. Topics included are: (1) "Principles of Nuclear Safety Research" (examining who should fund, who should conduct, and who should set the agenda for nuclear safety research); (2) "Elements of a Future Agenda for Nuclear Safety Research" (outlining a number of particular research topics on which additional research is needed or might be better focused); and (3) "Eliminating Barriers to an Effective Program of Nuclear Safety Research" (discussing organizational and management issues, and recommending ways to improve research sponsored by the National Research Council). A bibliography contains about 100 references. Appendices include a list of the sponsors of commercial nuclear research and development; some programs of the National Regulatory Commission, the Department of Energy, and the Electric Power Research Institute; a questionnaire on nuclear safety research; a list of participants in committee hearings; and biographical sketches of the committee members. (YP)

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REVITALIZING NUCLEAR SAFETY RESEARCH

Committee on Nuclear Safety Research
Commission on Physical Sciences, Mathematics,
and Resources
National Research Council

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Washington, D.C. 1986

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Support for this project was provided by the U.S. Nuclear Regulatory Commission.

Available in limited supply from the Commission on Physical Sciences, Mathematics, and Resources, 2101 Constitution Ave., Washington, D.C. 20418

Printed in the United States of America

NATIONAL RESEARCH COUNCIL
COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND RESOURCES
2101 Constitution Avenue   Washington, D.C. 20418

COMMITTEE ON NUCLEAR SAFETY RESEARCH

December 8, 1986

The Honorable Lando W. Zech, Jr.
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Chairman:

I am pleased to present the report, "Revitalizing Nuclear Safety Research," by the National Research Council's Committee on Nuclear Safety Research. The subject of this report is an important one, both because of the number of operating commercial nuclear power reactors whose safety must be assured and because of the continuing level of operating problems, which the committee believes stem, at least in part, from an inadequate base of knowledge, which could be provided by a satisfactory continuing program of research.

While we believe the report speaks for itself, there is one aspect of it that I believe deserves special comment. It is never easy for a committee to achieve a strong consensus, and all committee utterances must be taken to be weaker than the views of individual members. I believe that in this case, however, there is general agreement within the committee that many of the problems that the Commission has been having with its research program stem from problems inherent in the current structure of the Commission, its internal communication, and its operating practices. A discussion of these issues is presented in Chapter 4 of the report, "Eliminating Barriers to an Effective Program of Nuclear Safety Research." I might add that my personal views in this matter are particularly strong: it is difficult for me to see how the Commission can function effectively given its current structure. As will be clear from Chapter 4, such a conviction is not the same as knowing what structure would be better; should there be a real desire for change, that problem is left as an exercise for the Congress, the Administration, or some successor advisory group.

The Soviet nuclear accident at Chernobyl occurred after the committee had completed its active period of meetings and consultations. While the committee was not able to have a fully informed discussion of that accident, there was enough exchange of ideas for us to be able to say that a more in-depth treatment of the events at Chernobyl would be unlikely to result in real changes in the report. Perhaps further discussion would lead us to place even greater emphasis on the issues of human factors, instrumentation and control, and operations, but the report already calls for more intensive research in those areas.

If there is any way in which the committee can help make the report more useful to the Nuclear Regulatory Commission, we hope you will call on us.

Very truly yours,

Robert A. Frosch
Chairman

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Preface

The Committee on Nuclear Safety Research was formed by the National Research Council in response to a request from the U.S. Nuclear Regulatory Commission (NRC) to conduct an independent, one-year study of the future role of the NRC's program of regulatory research. The committee was asked to develop fundamental principles of nuclear safety research based upon examination of the following questions:

1. What can be said at present about the information needs that will be confronted by those who regulate nuclear power in the 1980s and 1990s that can be met, in part, through new research?
2. What are the alternative mechanisms for producing these research results and the relevant strengths and limitations of each?
3. What, if any, advantages accrue from federal support of undirected research in nuclear safety, including replenishing the pool of scientific talent available to address specific problems as they arise?
4. What are the implications of the findings for questions 1 through 3 above for the scope, structure, and coverage of the federal program, given current statutory requirements?

At its first meeting, the committee was asked by the then chairman of the NRC, Nunzio J. Palladino, to address a slightly different set of questions. Though Chairman Palladino's questions overlapped those included in the formal charge to the committee, they also raised a broader set of issues. The committee was asked to answer the following questions:

- Did the committee agree or disagree that more research is needed?

- If it agreed that more research is needed, what program of research did the committee feel would anticipate future regulatory problems? If it disagreed, how fast did it feel that current efforts should be phased out?
- Is it better for licensees to do the research, only the NRC, or some mix? If a mix, what should that mix be?
- Should federally funded research be aimed at specific problems as they arise or at broader issues in anticipation of specific problems?
- To what extent should research work be focused solely on explicit, near-term objectives? If any other type of research work should be done, how should it be guided?
- What is the potential value of retaining a general pool of scientific and engineering talent that could be directed to work on specific problems as they arise?

Because of Chairman Palladino's desire to have the committee address issues of nuclear safety research in this broader context, the committee's report occasionally touches on matters that go beyond the formal charge.

In addition to developing principles of nuclear safety research, which was the committee's primary responsibility, the committee initially intended to examine what research was being done and what would be needed in the future, and to make recommendations as to whether the current program of research should be modified, expanded, or contracted. However, the committee early in its deliberations reached the general conclusion that management problems within the NRC made it unlikely that any detailed modification of the content of the NRC research program would lead to significant improvement. As discussed in the report that follows, the committee was drawn to this conclusion because it found a program that lacks direction and a coherent and effective set of principles for organizing an integrated program of research. Consequently, the committee was compelled to focus primarily on the fundamental building blocks of a safety research program and on making recommendations that would improve NRC management of research. In the committee's judgment, it was less meaningful for the committee to address whether the right research was being done than to confront the institutional problems that the committee did address.

The membership of the Committee on Nuclear Safety Research reflected the diversity of backgrounds necessary to perform the work assigned to it. The committee included a former chairman of the NRC; a former assistant director to the late Admiral Hyman G. Rickover in the naval nuclear program; and a former senior member of the policy planning staff of the Department of Energy (DOE). It included several members who had experience managing or conducting nuclear safety research at federal laboratories; several who had managed or conducted research while working in the electric utility, nuclear supplier, or engineering consultant industries; and several who had performed nuclear safety research while in positions in academia. Two members had experience managing and conducting research either for French or Canadian utilities and regulatory agencies; another had participated in adjudicatory hearings before and litigated civil cases against the NRC; and several others had both scientific/engineering and policy analysis backgrounds but had no direct experience working either for the nuclear industry, the NRC, or the DOE. Finally, the committee was fortunate in being able to call upon the advice and assistance of Dr. Robert J. Budnitz, a former director of the NRC's Office of Nuclear Regulatory Research. During the study, Dr. Budnitz was a member of the National Research Council's Energy Engineering Board, and he served throughout the study as liaison between the board and the committee. Although not formally a member, Dr. Budnitz was in every other respect an integral part of the Committee on Nuclear Safety Research

During the period from November 1985 through May 1986, the committee held four public meetings, each of two days duration, for the purpose of obtaining the views of individuals knowledgeable about the nuclear safety research enterprise. From the NRC, the committee heard from the chairman and three of four other commissioners; from both the current executive director of operations and his predecessor; from current and former directors of the Office of Research; from senior staff members of the Office of Research and the Office of Nuclear Reactor Regulation; and from two senior members of the Advisory Committee on Reactor Safeguards. The committee also heard from senior members of the staffs of the DOE and the Office of Management and Budget (OMB); from representatives of electric utilities, reactor vendors, the Institute of Nuclear Power Operations (INPO), and the Electric Power Research Institute (EPRI); from senior staff at DOE national laboratories currently responsible for managing programs of nuclear safety research; and from university faculty. In addition, the committee and its staff prepared a series of questions on nuclear safety research that were addressed not only to those who appeared before it but to more than 200 others active either in sponsoring, conducting, managing, using, or evaluating nuclear safety research. In its deliberations, the committee relied on the material from its hearings and written replies to its questions; on documents made available by the NRC, DOE, and EPRI; and on its members' experience in R&D management and science policy formation and their personal knowledge of the programs and budgets of organizations engaged in nuclear safety research.

The committee immediately recognized that, in order to be manageable, the scope of the study would have to be circumscribed. Had the committee employed the broadest definition of "nuclear safety research," it would have faced enormous difficulty in addressing the issue in the limited time available. The committee therefore decided to limit its attention to research connected with the safety of commercial nuclear power reactors, giving essentially no attention to other important issues, such as the safety of naval propulsion reactors, the safety of defense production reactors, the safe production and use of radioactive isotopes, or the safe disposal of high-level nuclear wastes or other activities associated with the use of nuclear materials (e.g., uranium mining and milling, fuel fabrication, enrichment, and transportation).

Had the committee focused on the technical issues of reactor safety research rather than the institutional ones, there would have been need for far more discussion of foreign programs than is presented in this report.

Executive Summary

This report reflects the committee's conclusions on the general issues involved in nuclear safety research. The message that the committee hopes to convey is that nuclear safety research in the United States could benefit from strong leadership from the U.S. Nuclear Regulatory Commission,* leadership that has not been forthcoming in the recent past. The report specifies areas needing detailed consideration. In particular the committee has tried to take a systematic approach to nuclear safety research, to point out the general principles involved, and to elucidate some of the implications of these principles for decisionmaking in the public and private sectors. There has been no attempt to produce a detailed research program or budget—that is more properly a task of others. But the report does indicate areas where too little is being done or where the research effort would benefit from being refocused.

It is hoped that special attention will be paid to the general principles here enunciated and to ways in which they might be applied in the operation of the NRC's program of research.

The main body of the report is contained in Chapters 2, 3, and 4. Chapter 2, "Principles of Nuclear Safety Research," examines who should fund, who should conduct, and who should set the agenda for nuclear safety research. Chapter 3, "Elements of a Future Agenda of Nuclear Safety Research," outlines a number of particular research topics on which additional research is needed or on which research might be better focused. Chapter 4, "Eliminating Barriers to an Effective Program of Nuclear Safety Research," discusses organizational and management issues, and recommends ways to improve research sponsored by the NRC.

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* From this point on throughout the report, the U.S. Nuclear Regulatory Commission will be referred to as the NRC for the sake of brevity. The acronym should not be confused with that of the National Research Council, which is not mentioned in the report in abbreviated form.

CONCLUSIONS AND RECOMMENDATIONS

The committee reached the following general conclusions about nuclear safety research:

1. There are general principles for helping to answer the set of questions, "Who should pay for, who should carry out, and who should establish the agenda for nuclear safety research?" These principles, discussed in Chapter 2, require adjustments in the current practices of the NRC and in the pattern of institutional involvement in nuclear safety research.
2. Research on matters related to the safety of commercial nuclear power reactors should continue to be performed. Chapter 3 contains a list and discussion of some of the areas in which the committee believes research should be continued or begun.
3. Serious management problems affect the research program of the NRC, but there are well-known practices of the general research and development community that can be used to help solve some of these problems. Both the problems and possible routes to their solution are discussed at various points in the text, particularly in Chapter 4.

After formulating its principal conclusions, the committee did not seek to reanalyze the current program with an eye toward constructing and estimating a budget. That would require, among other things, a rigorous technical analysis of the relative merits of different areas of research, a task that the committee was not able to undertake in the time available.

For the past five years, the budgets of the federal agencies responsible for research on commercial nuclear reactors have been under attack. These pressures partly reflect the response of the Reagan administration to the nation's burgeoning federal deficits and to federal spending in general. They also reflect the administration's view that the private sector ought to be playing a much larger role in virtually all matters related to nuclear regulation.

The budget debates have served to highlight a fundamental disagreement among federal policymakers concerning the appropriate scale and scope of the government's responsibility for nuclear regulation in general and nuclear safety research in particular. In each of the past five years, the outcome of these debates has been reductions in support for nuclear safety research.

The committee recognizes that in the real world when budgets get cut the first things to go are those that do not have obvious, immediate, guaranteed payoffs. This is what has happened to the federal program of nuclear safety research. Nonetheless, for any level of effort in the nuclear safety research program, the leadership and support must be there to carry the research through. The committee sees little to suggest that those most responsible for the federal program of nuclear safety research—whether in the responsible federal agencies, Congress, or the Office of Management and Budget (OMB)—appreciate the necessity of providing the requisite leadership.

The following summary presents the principal findings of the report as drawn from Chapters 2, 3, and 4. Chapter 4, in particular, sets forth most of the committee's detailed recommendations.

Principles of Nuclear Safety Research

To determine who should set the agenda and who should fund nuclear safety research, the committee began by examining the question, "Who benefits by learning the results of this research?" From this the committee reached the following guiding principles:

- Use the best facilities and the best people, without undue regard for whether they are affiliated with a national laboratory, a university, or industry.
- Use systems and procedures that will ensure the integrity and independence of the result; care should be taken to assure that all laws relating to conflicts of interest are obeyed, and procedures should be used that can guarantee, independently of the NRC staff, the quality and integrity of the results.

Viewing the federal program of nuclear safety research in light of the above principles, the committee makes the following recommendations:

1. The U.S. government should continue to fund research on the safety of commercial nuclear power reactors.

2. Nevertheless, an increased proportion of the research should be funded and conducted by the industry (utilities, suppliers, and vendors) than is now the case.

3. Direct NRC funding of research should continue.

4. The Department of Energy (DOE) and the NRC should encourage more research funded cooperatively with industry or with international partners.

5. Universities and other contractors with relevant knowledge and skill should be more actively involved in setting the research agenda.

6. Research funded by the NRC should be the product of a competition among the DOE national laboratories, private contractors, and university researchers.

7. The U.S. government should maintain programs of long-term and exploratory research and maintain effective nuclear engineering programs of the quality and quantity needed by the country at the university level. If private industry is unwilling or unable to sustain the university programs necessary for producing the trained personnel that the government needs to conduct an effective program of nuclear safety research, then it is sound public policy for government to do so.

8. In principle, the committee believes that internalizing the costs of research in a regulated industry—such as the electric utility industry—is desirable, and that ways of accomplishing this should, if possible, be adopted.

Elements of a Future Agenda for Nuclear Safety Research

The committee believes that not enough research is being done on certain topics important to the future regulation of nuclear power plants. In particular, the committee members believe, based upon their collective experience, that research should be intensified in these areas:

- Behavior of materials in nuclear power plant environments
- Human factors
- Nondestructive testing
- Nuclear power plant aging

- Policy research
- Research to reevaluate existing regulations

In addition, research on the following topics should be continued but refocused:

- Component and systems reliability
- Nondestructive examination
- Quality assurance/quality control
- Safety analysis methodology and application
- Severe accidents

A future research agenda must include mechanisms for deciding the proper end-point of specific research topics. In research, every answer results in a new set of questions which might be addressed. The relative importance of the topic to real safety issues should be used as the basis for deciding whether to pursue or terminate further research.

Eliminating Barriers to an Effective Program of Nuclear Safety Research

There are many structural and procedural problems that the NRC must address if it is to have a sound research program. The committee's recommendations for improving NRC management call for changes in the way the director of research, the executive director of operations, the NRC itself, the Office of Management and Budget, and the Congress currently discharge their responsibilities.

1. The NRC Director of Research must establish and maintain good, fundamental research practices, including the following:
   a. Use of the best researchers to perform the research.
   b. Establishment of a coherent planning process.
   c. Routine use of peer review to instill confidence in the quality of research results.
   d. Establishment of a strong advisory group that includes independent experts from industry and academia, along with representatives of organizations performing research.
   e. Strengthening links between the Office of Research and the intended users of research.

2. The executive director of operations should take responsibility for the kind and extent of communication between the NRC program offices to ensure that they work closely together in designing and coordinating the program of research.

3. The chairman of the NRC must exert leadership in establishing the NRC research program and defending it before OMB and the Congress.

4. Options for restructuring the NRC to restore leadership to nuclear safety research, including the possibility of reorganizing the NRC to provide for a single administrator, should be reexamined. Some aspects of such a reexamination are beyond the scope of the NRC and are for Congress and the administration to consider. Whether or not Congress enacts legislation along these lines, both OMB and the Congress should support a level of funding for nuclear safety research that is appropriate to the continuing federal responsibilities for nuclear safety research.

1
Introduction

Nuclear power generation is a complex process encompassing both high technology and conventional engineering activities. It is replete with all the promises and problems that such activities typically entail. Ordinarily, some of the problems of a complex technology are uncovered and resolved during the period of maturation. Forty years after the beginning of the nuclear age, nuclear technology is still going through a period of development; for example, none of the larger power reactors has reached the end of its design life. This underscores the importance of research and the continuing need for better understanding of reactor behavior under varying conditions, from normal operations, through off-normal conditions, to accidents.

Effective research in nuclear safety—research that is capable of asking as well as answering the right questions—requires not only scientific and engineering credentials, but also an intimate knowledge of a large number of specific scientific and engineering issues pertaining to nuclear power plant operations. These are for the most part not available in textbooks; they are acquired through personal involvement with nuclear technology, reactor safety, power plant operations, regulatory matters, and research over a long period of time.

The primary benefits of research and of achieving a better understanding of reactor behavior are improved designs, improved modes of operation and maintenance, and improved regulation of nuclear power plants. One of the intermediate goals of safety research is to establish margins of safety as new issues arise and to refine the quantitative margins in existing regulations that are thought either to be overly conservative or not conservative enough. The committee would like to point out, however, that even an excellently managed, well-funded, and appropriately focused program of nuclear safety research cannot transform the regulation of nuclear power plants into a process in which decisions flow exclusively from scientific and technical knowledge. Like all environmental, health, and safety regulation—indeed all decisionmaking on highly technical subjects—nuclear regulation will always remain a complex blend of applying knowledge and exercising policy discretion.

Many of the current regulations have been in force for the entire history of nuclear regulation; they are likely to require review and change in light of new knowledge. As new events occur, there are new lessons for safe power plant design, construction, and operation that need to be reflected in industry practices and in regulation. Regulators need to develop new tools—both analytical and experimental—with which to analyze emerging safety issues. For all these reasons, safety research is absolutely essential. And it can only be expected to remain so because the range and complexity of physical phenomena affecting the operational safety of nuclear power plants are likely to increase as nuclear reactors age, as plant operating conditions change to accommodate aging, and as the performance of plant personnel varies in response to changing conditions.

During committee discussions it became clear that the activities being thought of whenever the term "research" was used—indeed those historically considered to be research by the DOE, the NRC, and the nuclear industry—included a much broader range of activities than are ordinarily thought of as "research." It was evident, however, that all parts of the broad range of activities being considered are so closely connected that they must be considered together in planning and executing a program of nuclear safety research. Accordingly, the committee elected to use a broader meaning for "research" than is customary.

In this report, the term "research" is used as a shorthand expression for a variety of activities commonly referred to as "research," "development," "test," "evaluation," "audit," "analysis," and "investigation." It is meant to encompass both safety research and safety engineering, activities that aim either at applying existing knowledge or creating new knowledge in the field of nuclear safety. A categorization of these kinds of activities is presented in Table 1.

TABLE 1 Nuclear Safety Research Activities

Experimental investigation
- o fundamental physical constants and properties
- o component behavior
- o system response
- o verification

Theoretical investigation
- o component, system modeling and validation
- o development of safety technology
- o development of conceptual component and system designs

Design analysis
- o failure modes and effects
- o prevention/mitigation strategies
- o human performance predictions

Operational analysis
- o review of operating data
- o performance testing
- o potential for systems improvements

The safety research activities outlined in Table 1 may be financed, funded, and executed by individuals or organizations, public or private. In the United States, the institutional context within which nuclear safety research takes place is extraordinarily complex in both the number and the kind of participating organizations. Table 2 provides a list of some of the major participants, and Appendix A discusses the roles of the leading sponsors of commercial nuclear safety research.

TABLE 2 Participants in the Nuclear Safety Research Enterprise

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Government

- Nuclear Regulatory Commission
- Department of Energy (including the national laboratories)
- Geological Survey
- National Bureau of Standards
- National Science Foundation

Industry

- Electric Utility Industry
  - (a) individual firms
  - (b) ad hoc utility projects (e.g., IDCOR)
  - (c) Electric Power Research Institute
  - (d) Institute of Nuclear Power Operations
- Nuclear Reactor Vendors
- Utility-Vendor Consortia (so-called Owners Groups)
- Architect/Engineers
- Component and Equipment Suppliers
- Engineering Consultants

Universities and other contract research organizations (e.g., Science Applications International Corp.)

Professional and technical societies

Foreign participants in international cooperative arrangements involving the U.S. government or U.S. firms

The public (through the licensing and rulemaking processes)

2

Principles of Nuclear Safety Research

During its study the committee was provided with evidence suggesting that members of the public, of the nuclear industry, of the Congress, and of the administration have little faith in the soundness of the federal government's program of nuclear safety research. One source of this lack of confidence is the failure of the government to organize and implement a program according to fundamental principles—principles of nuclear safety research.

The purpose of this chapter is twofold: first, to develop general principles of nuclear safety research; second, to examine some of the implications of these principles for decisionmaking in government and in industry. Chapter 3 illustrates how these general principles can be applied to a set of important research topics that represent elements of a future program of nuclear safety research for the nation. The reader should recognize that in discussions of research that principally benefits utilities or the NRC these organizations are being used as proxies for larger groups (viz., ratepayers and stockholders in the former case, taxpayers and the public in the latter case).

THREE CENTRAL QUESTIONS

There are three major questions from which fundamental principles of nuclear safety research can be derived:

- Who should fund nuclear safety research?
- Who should set the research agenda?
- Who should conduct the research?

"Who should fund the research?" asks from which organization's budget should the research be funded. "Who should set the research agenda?" asks who should decide in what areas research is needed, what questions should be investigated, what research projects should be done, and how should meaningful projects be designed. And "Who should conduct the research?" asks which organizations or which researchers should actually carry out the research.

WHO SHOULD FUND AND WHO SHOULD SET THE AGENDA FOR NUCLEAR SAFETY RESEARCH?

The economics and science policy literature cite three basic reasons why industry usually underinvests in R&D relative to the level that would be socially optimal: (1) the uncertainties as to whether R&D investment will pay off make such investment highly risky; (2) most knowledge, once obtained, cannot be kept to oneself for very long, implying that the firm that pays for the R&D cannot appropriate to itself all the benefits from it; and (3) the cost of R&D projects are often large compared to what an individual firm can afford to invest. These reasons apply to the nuclear industry no less than to others. Indeed, the current state of the nuclear industry and the historical role of the federal government in nuclear R&D suggest that the nuclear industry might underinvest in R&D more than many other industries.

In many respects nuclear power is at a standstill in the United States; there have been no nuclear plants ordered for almost a decade, and dozens previously on order have been canceled. As a result of the industry's diminished prospects, nuclear reactor and equipment vendors cannot have a high expectation of being able to benefit from investment in safety research. The utility industry—the primary owners and operators of commercial nuclear power plants—is itself fragmented, so that sizable research investments are possible for only a handful of the larger utilities. With a few notable exceptions (such as in New York and California), utilities have traditionally relied upon reactor vendors for research on power generation technology. State public utility commissions, which regulate utility rates of return, have significant influence upon, and an incentive to limit, the size of utility budgets. In fact, there have been instances in which PUCs have restricted

the amount of money raised from utility ratepayers to fund EPRI research. There are thus both internal and external cost-cutting pressures that are likely to push the industry in the direction of avoiding expenditures whose direct contribution to operating efficiency is unclear. Finally, the federal government has a legacy of large investments in all facets of nuclear research and development, and this legacy has created a general expectation within the industry that the federal government should continue to bear a large measure of the responsibility for safety research. These facts, combined with the more general arguments cited above, imply that the nuclear industry may voluntarily fund less nuclear safety research than is in the public interest.

These factors need to be kept in mind in considering who should fund and who should set the agenda for nuclear safety research. In what follows the two questions are treated simultaneously, not only because they are intimately connected to one another but because there is no general answer to either one of them.

Principles for Determining Who Should Fund and Who Should Set the Agenda for Research

Logically, either government or industry or a combination of the two could be involved in funding research. If the government wants research, it has several means of getting it done. It can direct industry to do it, it can pay to have it done by others, or it can do it itself. If industry wants research done, it can either do it itself or pay to have it done by others. Agendas, on the other hand, may be set not only by industry and government but also by other performers of research and independent technical experts. In cases where both government and industry benefit from the research, they will have to work out the details of their respective funding and agenda-setting responsibilities on a case-by-case basis.

This discussion of who should fund and who should set the agenda for research is guided by the following general principles. They represent the committee's best judgment of what principles are applicable, and they derive not only from its study but from its views of the appropriate roles of government and industry in the nuclear safety research enterprise.

1. Where the proximate beneficiary of the research is industry, the presumption is that industry should pay for it. However, there

are countervailing considerations that can override that presumption.

2. Where the expected societal benefit of the research is greater than the expected return to industry, government should contribute to paying for it.

3. Industry should pay for much of the research necessary for the performance of the regulatory functions of the NRC, but the NRC should pay for research when it is necessary to protect its independence, assure the timely availability of results, or explore issues involving great uncertainty.

4. Anyone who pays for a piece of safety research should contribute to setting the agenda for that research.

5. Performers of research and independent technical experts should participate in setting the research agenda.

It is not always going to be easy to decide, a priori, who the principal beneficiary of some research may be. In the case of basic research, it is not always possible to say even if there is a beneficiary, much less who that beneficiary may be. Yet basic research is an essential feature of a sound program of nuclear safety research.

Implications for Decisionmaking

The application of these general principles has implications for decisionmaking in government and industry. Below we make a distinction between regulatory and nonregulatory research and between research on current and future reactors in order to explore these implications.

It should be noted that as a practical matter it is frequently not possible to make a sharp distinction between research to improve regulations and research to improve the design, performance, and safety of reactors. There are, of course, examples of research that is quite clearly directed at achieving some economic benefit but is of only marginal benefit either to safety or to regulation. Similarly, there are examples of research where the purpose is clearly to support improvement of regulation or the independence of the regulatory agency in the light of some vested industry position. In many cases, however, the public and private benefits of the research are mixed, and the overlap between regulatory and utility requirements is extensive, so that it is difficult to allocate neatly the responsibility for the research.

Category 1: Research on Current Reactors That is Aimed Directly at Improving Regulatory Decisions

The proximate beneficiary of research in this category is by definition the NRC, so it must have at least partial authority to set the research agenda. Yet the NRC does not and need not fund all research in this category since it has the authority to direct industry to fund it. It exercised such authority, for example, with respect to research on relief valve reliability; and it also exercised this authority when it initiated the reassessment of Babcock & Wilcox (B&W) reactors now being conducted by the B&W Owners Group.

The practice of directing industry to do research is more widely used by the nuclear regulatory authorities of other countries (notably Canada) and by other U.S. regulatory agencies (notably the Food and Drug Administration). It could also be used more widely by the NRC. Of course, the agency would need to employ safeguards to protect its independence. Such safeguards might include insisting that agency personnel have access to facilities and to the raw data from such work; requiring that the results be peer reviewed; and retaining within the agency, through the use of consultants or staff of the national laboratories, the ability to interpret the data and evaluate claims made by industry. With the employment of these kinds of safeguards, such an approach to nuclear safety research can and should be more widely used by NRC, and doing so would not jeopardize the NRC's independence.

When the NRC directs industry to do work applicable to a particular reactor, the work should be funded by the owner of that reactor; more generic research could be funded by licensees cooperatively through, for example, Owners Groups or through EPRI. In such cases, agenda-setting ought to be shared between industry and the NRC. The NRC should decide in what areas research is needed to address regulatory issues. The industry should decide what research projects would be responsive to the NRC, and how to design them, although these issues might be better decided after consultation with the NRC.

Industry cannot be directed to fund all research in this category. On the contrary, some of it will have to be funded by the NRC, with the agency also setting all aspects of the research agenda. This includes research where NRC's independence cannot otherwise be assured (e.g., research on emergency planning where the industry and NRC disagree on how much emergency preparedness is needed; research where not enough is known about the problem for the industry to be able to decide what to do or for the NRC to be able to specify exactly what research it should require industry to do; and research where the results are required more quickly than could be anticipated if industry alone were required to fund the work (i.e., where the NRC is more motivated to do the research rapidly than industry).

Since it is often difficult to determine whether industry or government is the proximate beneficiary for a piece of research, it will often be appropriate to adopt an intermediate approach, namely, "cooperative research." Cooperative research is research in which the NRC jointly funds and jointly sets the research agenda with either the utilities or the vendors or both. The record of such projects involving industry and the federal government has been uneven. One complaint about cooperative research is the difficulty of overcoming the adversarial nature of the regulatory system within which it is conducted. On technical problems that are linked to licensing, industry often tends to offer the NRC no more than it feels it has to for fear of triggering a time-consuming regulatory response. The NRC often believes that industry is dragging its feet, particularly on any problem where the two disagree fundamentally on the safety implications. The net result is for cooperative projects to get bogged down in seemingly endless meetings, at great cost in both time and money. Yet despite the potential obstacles, there are enough recent cases of cooperative research that are viewed as having been a success to suggest that more cooperative efforts should be encouraged. The NRC and industry need to work to reduce the atmosphere of mistrust that pervades their dealings with one another.

Within the NRC, most research should be funded by the Office of Research. Other program offices in the NRC have funds to perform short-term research that they may need to conduct regulatory activities. These funds are commonly referred to as "technical assistance," and they should continue to be available. Of course, in order to ensure the integrity of the research program, it is important for agency management to ensure that what is properly "research" and what is properly "technical assistance" come under the managerial authority of the appropriate NRC offices.

In the past, some research in support of the NRC's ability to regulate has been funded through international cooperation. Such cooperation is to be encouraged whenever possible as a way of spreading the cost of safety research among all potential beneficiaries.

Category 2: Research on Current Reactors Where the Research has Safety Implications but is not Directly in Support of Regulatory Decisions

Safety research on current reactors where the objective of the research is not directly aimed at supporting NRC's ability to regulate is conducted by both industry and government, in the case of the government, principally by DOE. The government has a role to play in funding and setting the agenda for such research. When the work is developmental, the government is fulfilling its responsibility to ensure that the nation has secure and safe future sources of energy and thus is benefitting the general public. Therefore the general public has a responsibility to pay for a portion of the cost of the research.

Much of the research in this category is and should continue to be funded by industry for its own purposes, including the following:

- Research to improve the product.
- Research to support claims about safety in proceedings before the NRC.
- Research in anticipation of the NRC's raising issues (so-called "defensive research").
- Research by entrepreneurs who perceive potential business opportunities in supplying utilities with new safety-related equipment or services.

In all these instances, industry should set the agenda for the research.

Ordinarily, government funding of any research in this category should occur in the context of government-industry cooperative research programs, and the research agenda should be jointly set by government and industry.

However, there are instances in which research of this type should be fully funded by the government. These are cases in which industry is unwilling to fund or contribute to research that, although primarily of benefit to industry, is nonetheless expected to have significant societal benefits. For example, research to develop specialized equipment or to test equipment used in other industries for possible use in the nuclear field may be constrained because manufacturers and suppliers have insufficient incentive to fund such work due to the limited scale of the nuclear market for such products. Research of this type should usually be funded by DOE because of its mission, although other agencies may also fund or conduct research with applications in the nuclear industry. In such cases, government should have the authority to set the research agenda, although this might be shared, either de facto or de jure, with industry and with the contract research community through appropriate advisory committees.

Although research that is not aimed directly at improving regulatory decisions is not of immediate interest to the NRC, it will often have implications for reactor safety that regulators must care about. For this reason, NRC participation in the funding of such research will, on occasion, be fully justified.

In the past, some research not in support of regulation has been funded through international cooperative arrangements. Such cooperation should be encouraged whenever possible as long as the original research objective is maintained.

Category 3: Research on Future Reactors

Research on future commercial reactors is conducted by DOE, which has no regulatory responsibilities in the commercial reactor sector. However, if future reactors ever become commercially viable, they will have to be regulated by the NRC and meet NRC safety regulations. Research on future reactors entails both safety and economic considerations. The research should be funded and the agenda set primarily by reactor vendors and suppliers as part of their development programs, particularly if a sufficiently early commercial payback can be anticipated. However, DOE has statutory responsibility for ensuring adequate future energy supplies and conducts an advanced reactor R&D program. DOE's decision on whether to allocate funds to advanced reactor research should be made on the usual grounds, i.e., whether the expected benefit of the research to society exceeds the expected return for the private sector, implying insufficient incentive for private investment in the research.

If DOE contributes to such research, the agenda will necessarily be set cooperatively. Even when DOE totally funds the

research, the potential users of the technology (i.e., reactor vendors and utilities) should participate in setting the research agenda in order to ensure that it takes account of market considerations.

The NRC needs to conduct regulatory research on advanced reactors in order to establish what safety standards these new designs must meet. Such work is a normal function of regulatory policy development, and in any case is not an important cost relative to other safety research activities. It is not practicable for industry to fund NRC's advanced reactor research since no specific applicant for an advanced reactor license yet exists. However, once the agency begins receiving applications for the review of advanced reactor designs, it could begin recovering from each applicant a portion of the costs incurred.

Here again, some research of this kind has been funded through international cooperation, and use of this mechanism of sharing the costs of research should be encouraged.

General Requirements for the Design of Government Research Programs

All government research programs, including the nuclear safety research programs of the NRC and DOE, have certain general requirements not considered in the foregoing discussion. These requirements are as follows:

- To support basic or exploratory research
- To ensure agency competence
- To ensure an adequate national pool of trained scientists and engineers.

Support for Basic Research

All government agencies that conduct research should support some research that is exploratory or basic in nature. The fundamental aim of this research is to continue the development of new knowledge. In theory, basic research could be funded either by industry or by government, but the usual reasons why industry tends to underinvest in basic research apply to the nuclear industry no less than to others. Therefore, government agencies, primarily DOE but also the NRC, should reserve some portion of their budgets for mission-oriented basic and exploratory research. The agenda for basic research will necessarily have to be set at least partly by the government, but both industry and the university research community can and should participate in agenda-setting through their participation in independent research advisory groups.

Ensuring the Competence of Government Research Managers and the Availability of Trained Scientists and Engineers

In principle, if the government has a vigorous program of nuclear safety research under way, no additional research will be necessary to fulfill either of these objectives. Furthermore, there are ways for the government to promote these two kinds of objectives other than by performing research. Nevertheless, some special research may be needed to ensure that the government is technically competent and aware of new developments in the relevant fields of science and engineering, and some may be required to ensure that researchers having specialized training and experience are available to perform research when needed.

At a time when the industry's fortunes are in serious decline, it is imperative that the government take a strong interest in the long-term availability of scientific and engineering talent—talent that will be needed to maintain agency staffs at a high level of capability and to conduct future research on safety-related problems. If NRC and DOE are to have effective safety research programs in the future, they must begin now to cultivate top-rate researchers and research managers, involve them over a period of years in the regulatory process, and support them in research on safety-related topics.

WHO SHOULD CONDUCT NUCLEAR SAFETY RESEARCH

When it comes to determining who should perform the research, there are several possibilities. Research might be conducted by the following:

- the government (e.g., NRC, DOE's national laboratories, U.S. Geological Survey, National Bureau of Standards);
- industry (including reactor vendors, equipment suppliers, utilities, including EPRI and consortia);
- the contract research community, including universities;

- an international cooperative arrangement involving the U.S. government or U.S. industry and one or more foreign governments or firms; and
- all combinations of the above.

All these combinations can and do exist because prime contractors of nuclear safety research often let subcontracts for a portion of the research they have been engaged to perform.

Principles for Determining Who Should Conduct Nuclear Safety Research

Despite the complexity of these arrangements for performing research, there are a number of principles that should be applied:

1. Nuclear safety research, like all research, should be conducted in institutions and by researchers who can do a good job. This principle encompasses both the competence of the researcher and his or her access to suitable facilities and equipment.

2. In deciding who should conduct research, where the principal objective of the research is aimed directly at improving regulatory decisions, care must be taken to protect the independence of the NRC from the regulated industry.

3. There must be institutional mechanisms to ensure that research results can be made available in response to short-term requirements without disrupting longer-term research.

4. Industry is a source of knowledge and expertise important to the conduct of nuclear safety research. When designing research programs, the problem of transferring the results of the research must be considered at the time agreements are reached concerning who should conduct the research and how the agenda should be set.

5. Universities have important roles to play as training grounds for future researchers, as centers of high-quality basic and exploratory research, and as sources of independent ideas.

6. National laboratories have unique experimental and computational resources as well as highly competent, experienced research teams of potential usefulness to a program of nuclear safety research.

Implications for Decisionmaking

The above principles have implications for determining who should conduct nuclear safety research. The process of selecting researchers is far from straightforward. The following discussion illustrates how these principles apply to research conducted in industry, in the university, in government laboratories, through international cooperative arrangements, or in the small business community.

Research Conducted in Industry

If the proximate beneficiary of a nuclear safety research project is industry, the research should involve industry to the maximum extent possible regardless of who pays for it. This is accomplished automatically, of course, when industry itself funds the research, when the NRC directs a licensee or applicant to conduct the research, when industry conducts research on contract either for the NRC or DOE, or when either of those agencies engages in government-industry cooperative research. Even NRC-funded research should often involve industry, except that where research results can be expected to directly influence regulatory decisions, care must be taken, in ways previously identified, to preserve the independence of the NRC. Where the facilities that are required for nuclear safety research exist only in the national laboratories, arrangements should be made to enable and encourage industry researchers to utilize these facilities; or the national laboratories should themselves conduct the research and help industry gain access to the results. In either case, industry should help set the research agenda.

Research Conducted in the Universities

University research is important for several reasons. It is a way of engaging some of the country's best theoretical and experimental scientists and engineers; it provides training for future government and industry researchers and research managers; and it fosters and encourages independent thinking about scientific and engineering problems. For all these reasons, the federal government has a fundamental responsibility to preserve and protect university research. For research related to current reactor types, the government's responsibility should be discharged primarily by the NRC; and for research related to more advanced reactor types, by DOE.

Research Conducted by the Government

The NRC and DOE do virtually no research of their own. When either of them wants research, they contract for it. The greatest part of the research supported by the NRC is conducted in DOE's government-owned, contractor-operated national laboratories. The national laboratories, in turn, distribute varying amounts of the work to other sectors through subcontracts. Of course, the NRC's enabling legislation directs the agency to make use of the national laboratories, and there are identifiable benefits to be gained by contracting with them. The laboratories provide ready access to experienced researchers from a wide variety of disciplines; they have instruments, equipment, and facilities that are sometimes not readily available elsewhere; their services can be obtained quickly through contracting procedures that are relatively easy for federal agencies to use; and they are accustomed to forming and maintaining interdisciplinary research teams. However, while the national laboratories have made identifiable contributions to nuclear safety research, and can continue to do so, they should be considered as only one among several alternative sources of quality research.

Research Conducted Through International Cooperation

Some nuclear safety research of interest to the United States is conducted jointly with other countries, both here and abroad. U.S. participation in these international arrangements for research is partially funded either by U.S. government agencies or by American industry. Examples include an international program of experimental research being conducted at the NRU reactor in Canada, a similar program at the Halden facility in Norway, and another at the Marviken reactor in Sweden. Foreign researchers sometimes participate in nuclear safety research in the United States as well. Such international cooperation in nuclear safety research should be encouraged whenever it is mutually beneficial.

Research in the Small Business Community

The United States has a long tradition of entrepreneurial creativity. The nation's small businesses provide major sources of invention and innovation and are quick to respond to the needs of industry. The contribution that small businesses have made to the country's nuclear safety research effort has been considerable and can continue. The DOE and the NRC should maintain their small business programs at the level necessary to exploit small business capabilities, whether or not the size of their research programs happens to be above the level at which a program of support for small business research and development is mandated by existing law.

Attaining Balance in Allocating Research Dollars

Determining who is best suited to perform a particular piece of research is one of the most challenging responsibilities facing directors of research. The challenge is particularly acute for the federal government's directors of research because several factors must be weighed in reaching a decision. These factors include not only finding sufficient talent and resources to do the job but also monitoring the impact of the selection process on the research community as a whole. To undernourish or overutilize any segment of the research community is to improperly manage the nation's limited resources for research. The committee is concerned that the nation's limited resources for conducting nuclear safety research have been poorly allocated in the past, particularly by the NRC. In Chapter 4 this issue is stressed, with the focus on the specific responsibilities of the NRC in contracting for research, and a reevaluation of the way the NRC allocates its research dollars is recommended.

A Final Note

It is important to recognize that in this chapter when the committee has focused on who should fund research it has been concerned with who should control the dollars being spent. A separate issue not addressed here is where those dollars come from. For example, even when the NRC provides funding, the dollars may flow from general revenues, license fees charged to particular nuclear utility licensees, or charges to reactor vendors for the review of standardized plant designs.

3

Elements of a Future Agenda for Nuclear Safety Research

In this chapter the committee identifies some important questions of reactor safety that should be researched. The principles introduced in the preceding chapter, where we looked at nuclear safety research in terms of several broad categories, are applied to each of these topics. The perspective here is narrower; the focus is on specific research topics that the committee believes should constitute elements of the nation's future agenda for nuclear safety research.

The list of specific issues that the committee has assembled is presented in Table 3. The table presents in alphabetical order a selection of important topics requiring research. The committee was asked to review a draft report, "NRC Safety Research Program," by the staff of the NRC, which outlines a small number of research topics they wish to pursue—component aging; thermal hydraulic transients; severe accidents; plant operations; seismic analysis; and waste disposal—and a seventh (advanced reactors) by implication. All of those topics, except regulatory waste management research, are discussed below, along with others that the committee finds important.

It is appropriate to reiterate that the focus here is exclusively on reactor safety research and, within that sphere, almost entirely on research in support of current reactors. Other aspects of the nuclear fuel cycle, in particular radioactive waste management, and other important areas of research, such as radiobiology and the health effects of ionizing radiation, are beyond the scope of this report.

TABLE 3 Elements of a Future Agenda of Nuclear Safety Research

- Current Plant Designs
  - Behavior of Materials in Nuclear Power Plant Environments
  - Decommissioning
  - Extended Fuel Cycle
  - Human Factors, Instrumentation and Control, and Operations
  - Nondestructive Testing and Examination
  - Plant Aging (License Extension)
  - Policy Research
  - Quality Assurance/Quality Control
  - Reevaluating Existing Regulations
  - Reliability of Plant Components and Plant Systems
  - Safety Analysis Methodology and Application
  - Seismology, Soil Mechanics, and Structural Response to Seismic Events
  - Severe Accidents
  - Thermal Hydraulics
- Future Plant Designs

The discussion below is intended to point out that, whether or not new reactors are built, outstanding issues remain to be considered and significant research remains to be done if only to provide adequate support for the safety of current reactors. In some areas not enough research is being performed. Such areas include the behavior of materials in nuclear power plant environments, decommissioning, human factors, nondestructive testing, plant aging, policy, and reevaluation of existing regulations. In other areas one or more of the principal sponsors has a sizable program of research under way, and the primary need is to refocus the work. That category includes research on component and system reliability, nondestructive examination, quality assurance/quality control, safety analysis methodology and application, and severe accidents.

CURRENT PLANT DESIGNS

Behavior of Materials in Nuclear Power Plant Environments

Many of the research topics discussed elsewhere in this chapter necessitate basic, exploratory, long-term research on materials used in the construction of nuclear power plant structures, systems, and components. Topics such as plant aging, component and system reliability, nondestructive testing and examination, quality assurance/quality control, decommissioning, and research to reevaluate existing regulations, as well as the broad field of advanced reactor R&D, all require basic materials research. Materials science is a highly complex, enormously important field incorporating a number of scientific disciplines. It can and should be developed as a basis for future investigations of such issues as new fabrication processes for use during plant construction; corrosion and cracking of piping during normal operations; effects of pressure and temperature gradients and radiation extremes on piping and equipment; inspection frequency and inspection techniques; repair and maintenance procedures; occupational health and protection against radiation; and many other topics of relevance to plant safety, reliability, and maintainability. Basic and applied research on materials properties and the performance of materials in the different environments found in nuclear power plants are essential in providing a means of confirming the adequacy of existing operating parameters, inspection techniques, and operating and maintenance procedures.

This is research that industry, the NRC, and DOE all need, whether for shared or different purposes. Not surprisingly, the work is now performed largely on a project-by-project basis. Some basic materials science and engineering research should be undertaken as part of a cooperatively funded program involving industry, DOE, and the NRC.

Decommissioning

Although only a few of the smaller research and demonstration reactors face immediate decommissioning, all the larger commercial reactors will eventually be candidates. Decommissioning will require the development of a data base and a methodology, including advanced measurement techniques for determining the quantity and activity of induced radioactive isotopes in remote locations (e.g., concrete and shielding), for treating contaminated materials, for ultimate disposal (including packaging and shipping), and for analyzing the potential reuse of certain materials such as stainless steel.

A continuing research program is needed to anticipate the much larger needs for decommissioning that will inevitably arise in the years ahead. The NRC has part of the responsibility because it needs the research to set decommissioning regulations.

The NRC currently has a small program to transfer lessons learned from DOE's decommissioning of the Shippingport reactor to the NRC, but in general decommissioning research receives low priority within the agency, and no substantial research is being conducted. Industry has a responsibility to do research that will establish ways of satisfying the NRC's regulations. DOE shares part of the responsibility for decommissioning research not only because of its mission to conduct basic energy research but also because it has reactors that will soon require decommissioning. It currently is conducting a sizable program of research, the principal elements of which are the decommissioning of the demonstration reactor at Shippingport and the removal and analysis of the core of the damaged Three Mile Island reactor. The results of DOE's current program should be transferrable both to the NRC and to industry.

Extended Fuel Cycle

The economics of nuclear power are strongly determined by the availability of nuclear plants for electricity generation. The frequency and duration of refueling outages are among the factors that influence plant availability. If nuclear fuel were present in reactors for a longer period of time without reducing operating efficiency, nuclear plants might achieve greater availability and spend less for fuel fabrication, spent fuel storage, and waste disposal. However, extending the period between refueling outages could in some cases also extend the time between preventive maintenance and component and system testing. So extended fuel cycle research is aimed not only at demonstrating the safety of new fuels but also at demonstrating the safety of extending the period of time between scheduled outages.

Both industry (in this case the utilities and the nuclear fuel suppliers) and DOE have research programs on extending the useful life of nuclear fuel. To the extent that this research is motivated by economic considerations, industry should be primarily responsible for funding and setting the agenda for the research. DOE began research in this field at a time when uranium resources were thought to be at risk. The purpose of the research was to stretch those resources as far into the future as possible. With the current worldwide glut of uranium, this justification for the program is

reduced. Nevertheless, extended burnup fuels raise potentially significant issues for the management of the nation's high-level waste repository program, and DOE would be justified in conducting research to assess the potential impacts of high burnup fuel on waste packaging, handling, and repository size requirements. At some point, the NRC may need to conduct confirmatory research in order to permit extended-life fuels to be licensed, but because the lead time for this research is likely to be shorter than the expected lead time to develop the technology, this research need not yet be done. Furthermore, when the time does come to engage in this research, the NRC should ensure that it is done but should not pay for it. This is a case where the NRC should direct industry to pay for the needed research.

Human Factors, Instrumentation and Control, and Operations

One of the most significant lessons of the accidents at Chernobyl and Three Mile Island is that the people who design, operate, maintain, and manage nuclear power plants make up a system every bit as important to safety as the major components in a nuclear plant. At any time of the day or night, plant operators must be ready and able to diagnose disturbances in plant operations and prevent them from leading to a major accident. We now have enough operating experience to know that human errors are a significant contributor to the class of reportable events that occur at nuclear power plants, and we also know from probabilistic risk analyses that human errors are a significant contributor to plant risk. Operating experience indicates that some errors can be triggered by the failure of instrumentation and control systems to operate reliably and to assist operators in preventing events from occurring that challenge plant safety systems. Still others can be related to faulty or improperly executed operating and maintenance procedures.

Instrumentation and control system research should aim to provide (1) diagnostic aids and instrumentation for nonsafety systems so as to reduce human errors and improve early diagnosis of incipient failures, and (2) new techniques and instruments, including sensors and microprocessors, for on-line calibration and testing.

All these areas—human behavior, instrumentation and control, and operations—are in fact related to one another and belong within a single category of human factors research. Human factors research encompasses two broad areas and the following topics:

For normal operations:

- control room management
- maintenance management
- training in plant operations and maintenance
- management of the interface between control room operation and maintenance
- optimization of the division of labor between human operators and plant systems, including development of expert systems

For accident situations:

- development of sensors, displays, and redundant instrumentation
- development of real-time simulators for training
- development of improved accident diagnostics
- analysis of operating crew behavior
- emergency operating procedures, including development of expert systems
- integration of human factors engineering into the design of safeguards and other engineered safety features

Both the federal government and industry have responsibilities in human factors, instrumentation and control, and operations research, but the government has very little activity of this kind focused on existing reactors. For its part, industry should be funding an integrated program in these areas. But because industry views the NRC licensing process as an impediment to incorporating advanced technology into current plants, there is little likelihood that an integrated effort will be forthcoming. For this reason the federal government must establish a base program that encompasses these various areas and seek to play a leading role in encouraging the transfer of advanced technology for improving human reliability to the nuclear industry. At present, the NRC has almost no program whatsoever, and few national laboratories have much human factors expertise. The bulk of the expertise is in industry outside the nuclear field.

The NRC must sponsor this kind of research because without a major program of its own it will be slow to respond to the improvements currently being developed in some of the rapidly changing technologies in this field, such as process control. Many of the technical fields properly included within human factors research are so new that the NRC will need its own independent research program just to keep track of developments. Perhaps the crucial point to be made is that the NRC needs to establish a regulatory climate that encourages technological advances in the area of human factors, rather than one that is merely neutral with respect to it, as is now the case. DOE should fund and direct its contractors who operate DOE reactors to perform research in all of these areas, because the research is needed for the continued safety of DOE reactors, because it is largely developmental, and because new technology is not required for commercial reactors by existing regulations. DOE's advanced reactor R&D programs can be expected to produce results applicable to existing plants. The agenda for this research should be set cooperatively by industry, the NRC and DOE.

Nondestructive Testing and Examination

Nondestructive testing (NDT) and nondestructive examination (NDE) are important technologies for in-place examination of nuclear power plant equipment and systems so that early indications of degradation can be obtained. In principle, NDT and NDE can provide crucial data necessary for determining when to make repairs and modifications to plant components. Further research is needed to develop NDT capabilities not now available, to refine the sensitivity and accuracy of the techniques now in use, and to develop and validate the reliability of advanced methods such as acoustic emission technology. Research is also needed to develop methods for extending NDT to reactor internals.

Both the industry and the NRC have relatively large programs in NDE. EPRI sponsors an NDE center in North Carolina, and the reactor vendors and other contractors have established service businesses supplying NDE and NDT techniques to the utilities. The NRC is sponsoring research in this field in order to be able to confirm the applicability and reliability of NDT and NDE techniques used by licensees. Certain types of nondestructive examination and testing are relatively new and could provide new technical approaches to monitoring plant component and system degradation. Because of this promise, the NRC and industry programs in this area should dedicate a portion of their funding to basic and exploratory research.

Plant Aging (License Extension)

Current operating plants were licensed to operate for either 30 or 40 years, depending upon when they were built. Some of these have licenses that begin to expire during the 1990s. It is common practice in the United States to extend the lifetime of large industrial facilities beyond what was anticipated when they were built, especially if they are capital cost-intensive. The nuclear industry believes that this will be especially appropriate for those nuclear power plants where no major licensing issues are outstanding and where the capital cost of the facility has been fully paid off. Because the cost of capital is the major component of the cost of nuclear-generated electricity, electricity produced by such plants is relatively inexpensive. These economic considerations, coupled with the current reluctance of utilities to consider building new capital plants of any kind, mean that there will be increasingly intense pressures to keep existing nuclear power plants running as long as is safely possible. In order to extend the life of plants now in operation, the utilities will need to be able to have their operating licenses extended.

Consequently, the NRC needs research to enable it to define whether safe conditions for license extension can be found. This will be a difficult and challenging problem, because each request for a license extension will depend upon the operating history, design characteristics, and anticipated mode of future operation of each plant. Although there is work on plant aging in progress, both within the NRC and among the utilities and vendors, the committee has seen no evidence that the results are being used in a systematic way to develop an integrated approach toward life extension research and regulation.

The NRC needs and should fund research that will allow it to set new design margins and to evaluate the adequacy of existing ones under extended-life conditions. The utilities need and should fund research to prove that license conditions set by the NRC can be met. Because the industry has enormous incentives to conduct research in this area, it should play a major role in funding plant aging research. However, DOE also has a role to play because it needs the research to ensure the continued safety of DOE's production reactors, because it can provide industry with useful spin-offs from development work in other areas such as nondestructive testing and examination, and because it can provide industry with insights from efforts to design advanced reactors intended to operate for a long time.

Since this research is of mutual benefit to the NRC, the DOE, and the utilities, the agenda for plant aging research should be set cooperatively. Indeed, an integrated, well-thought-out program of research should be undertaken. The research should focus on long-term chemical damage to pipes, valves, and other components exposed to gases and liquids, on long-term radiation damage to core, structural, electrical, and instrument components, and on long-term effects of operational cycles on mechanical integrity (fatigue and wear). The program should analyze the ability of components and systems to function beyond their design life. Examples of specific research topics in this field include in situ weld-repair techniques; structural integrity of plant systems, including the long-term integrity of radiation-embrittled materials; on-line diagnostics to measure degradation, including nondestructive testing; and the effectiveness of in-place annealing on the brittle fracture behavior of reactor pressure vessels.

Policy Research

One of the primary purposes of nuclear safety research, especially that funded or required by the NRC, is to inform regulatory decisions. However, little systematic research has been conducted on the use of scientific and engineering knowledge in nuclear regulation—a context in which legal requirements, interest group politics, and the exercise of policy discretion by government decisionmakers are all at least as important as knowledge. Nor has research been conducted into what sort of knowledge is most useful or in what form it is most usefully presented to decisionmakers.

Neither the government nor the industry currently funds policy research focused on these issues. Their importance for the effective use of research results justifies a modest effort by both the NRC and the utility industry. One example of the role of such research is in seeking to reconcile the differences in perspective between geophysicists and engineers who design nuclear reactor components, structures, and systems (see below).

Quality Assurance/Quality Control

Good quality assurance practices are important elements in the design, construction and modification of nuclear power plants and have a direct bearing on safety. The construction of a nuclear power plant must proceed in an orderly manner, with a high degree of management control and quality review. Experience has shown that standard construction practices do not consistently ensure that these goals are achieved. Deficiencies in quality assurance/quality control (QA-QC) have led to costly delays in plant start-up and, in some cases, have contributed to cancellation of the plant.

Research is needed to develop techniques to evaluate the as-built condition of nuclear power plants, and to track these conditions over the life of the plants to ensure that repairs and modifications that were made to correct faulty conditions do not lead to future problems. Topics in this field include the reliability and efficiency of QA-QC practices, human factors in QA-QC, construction-induced anomalies and their repair, and QA-QC data base management. The aim of this research should be to establish the QA-QC systems for achieving safety and full compliance with codes and standards.

The market for improved light water reactors and other advanced reactors is likely to be contingent upon, among other things, the availability of QA-QC practices that afford greater assurance of quality in construction than is now typically being achieved. Research is needed to provide these improved QA-QC practices, including development of more effective systems of QA-QC documentation with advanced approaches to scheduling, configuration control, document control, records management, materials control, materials storage, inventory control, and testing. The goal of this research should be to develop superior alternatives to the current paper-intensive approach to quality assurance.

Industry has the responsibility to fund research in QA-QC; the NRC should not be funding research in this field. If the industry is unwilling to do the research, it would be more appropriate for the NRC to direct the industry to do it than to fund it itself. The agenda for QA-QC research should be set by industry, with the exception of research in direct support of the NRC's ability to regulate where the agenda should be set cooperatively. The agenda for any basic and exploratory work that may be required should be cooperatively funded and cooperatively set by DOE and industry.

Reevaluating Existing Regulations

Over the last 25 years the federal government has amassed a large body of codes, standards, criteria, regulatory guides, and rules with which to regulate the various aspects of the nuclear fuel cycle. These were incorporated, one by one, into the framework of existing regulations as they were issued. By now a number of these technical codes and standards are thought to be out of date, if for no other reason than because research in nuclear safety and in other fields has continually revised and augmented the store of knowledge in science and engineering. Furthermore, the industry has produced a base of operating experience that can be used to reevaluate the existing safety margins contained in the regulations. A systematic research program is now needed to evaluate the overall adequacy of the existing regulations, integrating modern scientific and engineering understanding and the accumulated lessons of plant operating experience into a more coherent system of regulations. As a consequence of this work, some currently outstanding safety issues may be brought to regulatory closure, and areas where further research is needed may be identified. But the real purpose of a program to reevaluate the existing regulations is to rewrite the regulations so that they are more consistent and more efficient in ensuring public safety.

Reliability of Plant Components and Plant Systems

Nuclear power plants in the United States average many more reactor shutdowns per year than their Japanese and French counterparts. The failure of plant components and systems has been a significant contributing factor in a number of these shutdowns. In many cases the components and systems that have failed (valves, valve operators, pumps, small turbines, control equipment) were not specifically designed for the nuclear industry; they are conventional equipment designed for many different industrial applications. Component failures can degrade plant protection systems and challenge the capabilities of the operating staff. The relatively large number of significant failures of components and systems in the last year illustrates the need for increased component and system reliability.

Additional research is needed to extend real-time monitoring to other components and systems, to develop better methods of monitoring component adjustments and calibration, to establish better data acquisition and analysis of component reliability, and to optimize programs of preventive maintenance. One goal of this research should be to achieve better understanding of the effects of different system parameters, such as pressure and temperature gradients and fluid flow, on the performance of plant components during transients. Developmental work should be undertaken to determine whether simplifications or other changes in the design of plant systems can be made to increase plant reliability, safety, and economy.

Because this is an area of research in which economic and safety objectives are virtually inseparable, it is a prime candidate for cooperative NRC-industry research. The NRC needs research in this field to confirm that the components in the plants it regulates are sufficiently reliable to meet overall safety objectives. The industry needs the same assurances, and it also needs improved plant availability. The Institute of Nuclear Power Operations in Atlanta is developing a component reliability data base that holds great promise for future research; both the utilities and the NRC can use this data base to further their research programs.

Safety Analysis Methodology and Application

Probabilistic risk assessment (PRA) is an analytical technique for evaluating plants and plant systems. Although there are significant uncertainties in the risk estimates derived from PRA, its techniques have been used to assign priorities to programs of research, design, and plant operations. When properly applied, these methods can assist in interpreting operating experience, in analyzing data on the reliability of components and plant systems, and in identifying potential contributors to severe accidents.

The development of PRA methodology necessarily resulted largely from generic studies of the elements of risk in nuclear plants and applications of the methodology to illustrative plants. The generic approach was, and to some extent still is, essential to the development and refinement of the methodology. Early generic risk assessments, however, were widely claimed to provide important insight into the extent of risk associated with nuclear plants in general. But a reading of the PRAs that have been conducted suggests that many, if not most, of the contributors to risk are plant-specific rather than generic in nature.

Experience suggests, therefore, that future PRA activities should be directed primarily at plant-specific studies. The primary value of the PRA is not the results it provides to the NRC but rather the knowledge, insight, and decisionmaking capability it can provide to the utility. The successful application of PRA techniques to specific plants requires the participation of the utility's operating staff, as well as physical examination and analysis ("walk-throughs") of the entire plant, comparing the plant as built against the plant's final design. Nevertheless, the NRC needs to be actively involved in developing methods to ensure that utility-sponsored PRAs are adequate and to ensure that it can independently evaluate their strengths and weaknesses and their implications for plant safety.

Further improvement of PRA methodology will result from its widespread application to specific plants. However, certain improvements are likely to require generic research. For example, the analytical treatment of human factors, dependent failures, and external accident initiators in PRAs are difficult areas that can benefit from additional research. The incorporation of recent severe accident research results into PRAs is another area where methodological advances should be sought. Some generic research may be needed to ensure that PRA results drawn from studies of different plants are comparable. Finally, additional research is needed to develop improved methods of identifying reactor accident sequences, plant-specific contributors to risk, and possible means of mitigating potential accidents. Both industry and the NRC should fund research on PRA methodology, and the agenda should be set cooperatively.

Seismology, Soil Mechanics, and Structural Response to Seismic Events

Current estimates of the risk posed by earthquakes contain large uncertainties and suffer from the difficulty of modeling seismic phenomena. Research in this field is needed on a broad range of issues, including responses of plant structures to dynamic loads, systems response of reactors to earthquakes (i.e., the impact of earthquakes on the extent of defense-in-depth), and soil-structure interaction.

The further research needed to evaluate and reduce these uncertainties will require the formation and use of a sizable data base on earthquakes, data on structural failures of industrial plants, and data from tests of component fragility under varying loads. It will also require better techniques for modeling complex soil-structure interactions and the response of structural, mechanical, and electrical systems to seismic motions.

Both the NRC and the industry have significant research programs in the earth sciences largely dedicated to data gathering. The collection of data, although helpful, will not eliminate fundamental differences of opinion about the likelihood of seismic events of various severities against which plants might be designed. In fact, there is no universally accepted methodology for interpreting seismic data, for extrapolating them into regimes for which no actual data exists, or for drawing conclusions from the data and applying those to regulatory questions. It is not surprising, therefore, that in this field the NRC and industry have a history of disagreement. Among the underlying causes of disagreement are important differences in perspective between earth scientists and engineers. Geophysicists tend to have a retrospective focus and to be more concerned with understanding a problem by eliminating uncertainty. They have played a leading role in the government's earth sciences research program and as advisors to the NRC and intervenors on earth sciences issues arising in regulatory proceedings. Engineers have a prospective focus and tend to be more concerned with solving problems and designing around uncertainties. Civil engineers have tended to play a leading role as earth sciences advisors to industry. This basic difference in perspective between the two groups has led to and probably will continue to result in an inability of technical experts relied upon by the NRC, utilities, and intervenors to reach consensus on earth sciences regulatory issues. The NRC and industry would be well-advised to seek ways to reconcile the difference. Involving both geophysicists and engineers in cooperative research or initiating a series of conferences to explore their disagreements might help.

The federal government has a substantial program of research in the earth sciences, carried out principally by the U.S. Geological Survey, much of it directly relevant to the safety of nuclear facilities. The NRC could benefit from better coordination and collaboration with the USGS program. In addition, the NRC needs to focus greater attention on the difficult problem of system and plant response to beyond-design basis earthquake-induced accidents.

Severe Accidents

One outgrowth of the accident at Three Mile Island was an increased emphasis on research to understand the phenomenology of severe reactor accidents and how to mitigate them. This research has led to significant advances in the state of our knowledge about the complex physical and chemical processes of severe accidents, but uncertainties remain concerning the adequacy of the computational methodology used to analyze severe accidents and the reliability of the experimental data base that supports it.

Long before the Soviet nuclear accident at Chernobyl, it was clear from severe accident research that the major source of risk to the public stems from accident sequences that threaten the integrity of reactor containment structures. One of the principal goals of future severe accident research should be to establish containment performance, and this will require further basic research on the physical and chemical processes relevant to severe accidents that might breach containment.

Both the NRC and the industry currently have large research programs on severe accidents. Nearly a quarter of the NRC program, in fact, is devoted either to research on severe accident phenomenology or risk assessments related to it. Severe accident research can be aimed either at preventing or mitigating severe accidents or both, although it is more often aimed at mitigating them. The committee believes that more research on accident prevention—including research to analyze the adequacy of alternative means of core cooling (such as "feed-and-bleed"); to analyze the effects of unusual transients that go beyond the design basis of the plant; and to improve plant-specific PRAs—is required now that the mitigation issues are being resolved.

This is an area in which both the industry and the NRC need data and where both need to be able to trust the findings.

Experimental work on severe accidents should be organized cooperatively by the industry and the NRC. Funding and agenda setting for methodology development, however, should proceed independently because the NRC should not be solely reliant upon industry in the evaluation of severe accident research results.

Thermal Hydraulics

Thermal hydraulics has been the dominant area of nuclear safety research since regulatory research began. Prior to the accident at Three Mile Island, nuclear safety research in thermal hydraulics was focused on reactor steady state conditions, reactor transients, and large-break, loss-of-coolant accidents. The focal piece of the NRC's early research was the Loss-of-Fluid Test (LOFT) program and the LOFT reactor at the Idaho National Engineering Laboratory. In many ways the legacy of LOFT—the perception of it as an enormously expensive, largely failed and mismanaged project, particularly before a management reorganization in 1977—still continues to dog the NRC program as a whole. Since Three Mile Island, however, the entire direction of safety-related thermal hydraulics research has changed; the emphasis now is on small-break, loss-of-coolant accidents and off-normal thermal hydraulic plant behavior (so-called "transients"). The principal reason for this focus is the recognition, based on operating experience, that complex transients are a more credible source of accidents than originally thought.

Research in this field has two principal aspects: large-scale computer codes and both large- and small-scale experiments. Future research should further analyze the response of existing plants to thermal hydraulic transients and develop more effective computational tools and numerical methods for modeling and simulating thermal hydraulic phenomena. Research should be designed to provide fast running versions of the existing suite of computer codes for use in nuclear plant analyzers and reactor simulators. These tools could provide analysts with better means of evaluating reactor response to upset conditions and provide reactor operators with better ways of testing emergency operating procedures. As computerized systems become faster, attaining both real-time capability and more realistic simulation, they can be expected to provide invaluable assistance in the training of nuclear power plant operators. Many of the existing codes contain bounding-type assumptions rather than realistic models. For advanced computer systems to be completely effective, therefore, substantial research will be needed to upgrade and validate the existing codes and to develop and validate new ones. The current codes are integral parts of the reactor licensing process, and they must be demonstrably valid and readily available to all who need them. In addition to complex transients, phenomena such as flow-induced vibrations, water hammer, and the off-normal behavior of steam generators are candidates for early further thermal hydraulics research.

Code validation and greater understanding of thermal hydraulic phenomena both depend upon the results of properly designed and conducted experiments. The United States has very few remaining governmental facilities for experimental thermal hydraulics research, and some of these are to be dismantled in a few years. New facilities are being planned or built abroad, including ROSA IV (Japan), BETHSY (France), and SPES (Italy), and U.S. researchers participate in work at some of them. These facilities have been designed specifically to study small-break, loss-of-coolant accidents and thermal hydraulic transients. Construction and operation of facilities for experimental research are time-consuming and expensive, but there is a continuing need for experimentation. The United States must plan on being an active participant in these international programs for the long term. Although the utilities have in the past participated in international work of this kind, the international character of the work indicates that the NRC has the principal responsibility for funding and helping to set the agenda for international experimental thermal hydraulics research. Nevertheless, EPRI can and should play an equivalent role.

The NRC needs thermal hydraulics research to regulate existing reactors. For example, the thermal hydraulic behavior of some reactors during small-break, loss-of-coolant accidents under station blackout conditions (e.g., pump seal loss-of-coolant accidents) are not well understood. The NRC needs to conduct sufficient research in this field to know whether industry has done the right work, correctly and competently, and what the research results mean. For these reasons, some research should be funded by NRC.

FUTURE PLANT DESIGNS

Because the work of this committee was sponsored by the NRC and because of the limited time available to do the study, the committee tended to focus primarily on the research program of the NRC. The NRC's mission is to regulate the safety of current reactors and to review the safety of reactor designs that industry wishes to build. As a result of the prevailing conditions in the industry and the constraints on the NRC's research budget, the agency is currently sponsoring no research on advanced reactor safety (except for a relatively insignificant amount of "technical assistance"). Essentially all such research is sponsored by DOE and by industry. As a result, the committee did not examine safety research on future plant designs in any depth.

Nonetheless, there is one comment related to public policy that the committee must make here. The NRC should now consider what research must be conducted (by the NRC and by others) relative to the safety of new reactor designs and, in particular, what standard of safety such reactors must meet. The urgency of having the NRC address these issues derives from the fact that a consideration of licensing requirements is a necessary part of plant design. Designing an advanced reactor without considering the NRC's safety concerns and regulatory requirements makes no sense, but designers will have no alternative unless the NRC provides adequate guidance. It is poor public policy to have DOE and industry funding advanced reactor research and development while the NRC has failed to lay the regulatory basis for such reactors. The Commission's recent policy statement on advanced reactors fails to provide the program of regulatory research on advanced reactors with the detailed guidance that it requires.

4

Eliminating Barriers to an Effective Program of Nuclear Safety Research

The previous chapters of this report explain why nuclear safety research is needed, identify principles for determining who should fund, who should conduct, and who should set the research agenda, and show how those principles might be applied in organizing the nation's future program of safety research. This chapter identifies barriers to an effective program of nuclear safety research that exist within the NRC and in its relations with OMB and the Congress, and it recommends steps that the committee believes must be taken to eliminate the barriers.

Most of the committee's recommendations can be implemented by administrative changes within the NRC, without any outside action. Some require the support of Congress and the administration. It is hoped that this report will provide the justification for these long overdue administrative reforms.

The U.S. nuclear safety research program is widely perceived to be in trouble. This view is based not only on the planned closing of all U.S. facilities for large-scale experimental research related to current commercial reactors and the steadily decreasing budget of the NRC, but also on the increasing difficulty the NRC has in explaining the value of its research program to OMB and to the Congress. The committee has not tried to determine and does not know what the right amount is for nuclear safety research. However, the committee does know that, while stable funding is important, stable funding alone will not produce an effective research program. An important source of the problems alluded to throughout this report is the management practices and structure of the NRC (see Figure 1). Until the NRC's management problems are addressed, there will be little basis for determining what level of support is the one at which funding should be stabilized. Even though the committee was not in a position to address the question of the "right" dollar amount for the NRC research program, it strongly believes that whatever the appropriate amount may be, more real value will be attained for each dollar spent on nuclear safety research if the reforms recommended below are implemented.

Needless to say, administering a multimillion dollar program of safety research is a formidable challenge. The director of research at the NRC is responsible for a staff of more than 200 professionals and for managing a range of activities involving literally hundreds of different participants and organizations. The director is responsible for the following:

- Staffing the program (devising and implementing guidelines and incentives that can be used successfully to recruit and develop a competent and dedicated staff of public servants who are interested in and capable of planning, contracting, and communicating the safety research program)
- Designing the program (coordinating with users and other research sponsors to set a research agenda that implements a sound safety philosophy) and following through (working with other NRC offices to ensure that the results of research are appropriately used)
- Contracting for the research (establishing a process that employs the best available procedures for identifying, hiring, and retaining the services of the most qualified researchers)
- Communicating and securing support for the program (negotiating the scope and direction of the program with the commissioners, the OMB, and the Congress, and explaining and justifying the program to the public)

The remainder of this chapter looks at nuclear safety research at the NRC from the perspective of the management responsibilities of the NRC director of research, the executive director of operations, and the Commission. It identifies a number of management problems that prevent the NRC program from being fully

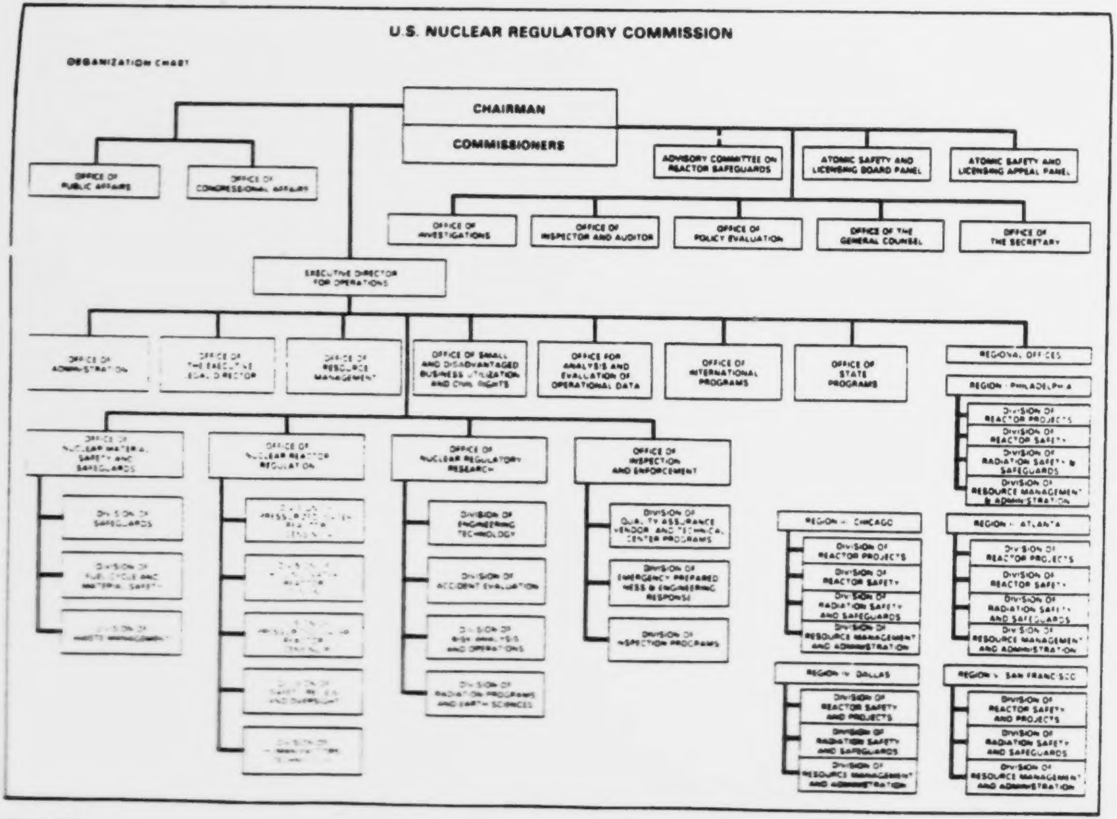
U.S. NUCLEAR REGULATORY COMMISSION
ORGANIZATION CHART
CHAIRMAN
COMMISSIONERS
OFFICE OF PUBLIC AFFAIRS
OFFICE OF CONGRESSIONAL AFFAIRS
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
ATOMIC SAFETY AND LICENSING BOARD PANEL
ATOMIC SAFETY AND LICENSING APPEAL PANEL
OFFICE OF INVESTIGATIONS
OFFICE OF INSPECTOR AND AUDITOR
OFFICE OF POLICY EVALUATION
OFFICE OF THE GENERAL COUNSEL
OFFICE OF THE SECRETARY
EXECUTIVE DIRECTOR FOR OPERATIONS
OFFICE OF ADMINISTRATION
OFFICE OF THE EXECUTIVE LEGAL DIRECTOR
OFFICE OF RESOURCE MANAGEMENT
OFFICE OF SMALL AND DISADVANTAGED BUSINESS UTILIZATION AND CIVIL RIGHTS
OFFICE FOR ANALYSIS AND EVALUATION OF OPERATIONAL DATA
OFFICE OF INTERNATIONAL PROGRAMS
OFFICE OF STATE PROGRAMS
REGIONAL OFFICES
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS
DIVISION OF SAFEGUARDS
DIVISION OF FUEL CYCLE AND MATERIAL SAFETY
DIVISION OF WASTE MANAGEMENT
OFFICE OF NUCLEAR REACTOR REGULATION
DIVISION OF PRESSURIZED WATER REACTOR LICENSING-A
DIVISION OF BOILING WATER REACTOR LICENSING
DIVISION OF PRESSURIZED WATER REACTOR LICENSING-B
DIVISION OF SAFETY REVIEW AND OVERSIGHT
DIVISION OF HUMAN FACTORS SAFETY
OFFICE OF NUCLEAR REGULATORY RESEARCH
DIVISION OF ENGINEERING TECHNOLOGY
DIVISION OF ACCIDENT EVALUATION
DIVISION OF RISK ANALYSIS AND OPERATIONS
DIVISION OF RADIATION PROGRAMS AND EARTH SCIENCES
OFFICE OF INSPECTION AND ENFORCEMENT
DIVISION OF QUALITY ASSURANCE, VENDOR, AND TECHNICAL CENTER PROGRAMS
DIVISION OF EMERGENCY PREPAREDNESS & ENGINEERING RESPONSE
DIVISION OF INSPECTION PROGRAMS
REGION I - PHILADELPHIA
DIVISION OF REACTOR PROJECTS
DIVISION OF REACTOR SAFETY
DIVISION OF RADIATION SAFETY & SAFEGUARDS
DIVISION OF RESOURCE MANAGEMENT & ADMINISTRATION
REGION II - ATLANTA
DIVISION OF REACTOR PROJECTS
DIVISION OF REACTOR SAFETY
DIVISION OF RADIATION SAFETY AND SAFEGUARDS
DIVISION OF RESOURCE MANAGEMENT AND ADMINISTRATION
REGION III - CHICAGO
DIVISION OF REACTOR PROJECTS
DIVISION OF REACTOR SAFETY
DIVISION OF RADIATION SAFETY AND SAFEGUARDS
DIVISION OF RESOURCE MANAGEMENT AND ADMINISTRATION
REGION IV - DALLAS
DIVISION OF REACTOR SAFETY AND PROJECTS
DIVISION OF RADIATION SAFETY AND SAFEGUARDS
DIVISION OF RESOURCE MANAGEMENT AND ADMINISTRATION
REGION V - SAN FRANCISCO
DIVISION OF REACTOR SAFETY AND PROJECTS
DIVISION OF RADIATION SAFETY AND SAFEGUARDS
DIVISION OF RESOURCE MANAGEMENT AND ADMINISTRATION

FIGURE 1

effective, and it makes recommendations that the committee believes could lead to a more effective program of nuclear safety research.

STAFFING THE SAFETY RESEARCH PROGRAM

During the last decade some very good work has come out of the NRC research program. Nonetheless, over the same period of time there has been a continuing erosion of research competence within the Office of Research, an erosion that seems to have accelerated after the 1981 merger of the Office of Research with the Office of Standards Development. Information presented to the committee indicated that fewer and fewer of the senior NRC research staff are experienced in actually doing research, as defined in this report, and that the recruiting of truly first-rate researchers may have become even more difficult for the NRC than for other federal agencies.

The committee therefore recommends:

1. The NRC should bring in some high-caliber people with active research experience to bolster top and middle management of the Office of Research.

The committee recognizes how difficult this may be. Lack of widespread public support for nuclear power raises the level of uncertainty about career prospects within the field and reduces the pool of prospective researchers and research managers. In implementing this recommendation, it would clearly be preferable if the NRC could attract experienced researchers who were willing to make long-term commitments to the agency. One potentially beneficial (albeit unintended) side-effect of the downward trend of funding for nuclear safety research is that it may have made available qualified researchers for agency employment. Nevertheless, experienced researchers may not be willing to make commitments to the NRC. Because the need for experienced research managers is so great, the agency should consider hiring experienced researchers even if they are available only for short-term (two-year) leaves of absence from permanent positions elsewhere in or outside the federal government.

In 1980 the Commission combined the Offices of Research and Standards Development under the then standards director. Over the ensuing period the research manager positions have been gradually filled by former members of the standards staff. The original intent of the merger was to provide a better transition from research result to effective regulation. Unfortunately, the result has been more for regulatory formalism to displace technical competence and experience in the management of the research and thereby to diminish the effectiveness of the program.

The committee recommends:

2. The NRC should consider separating the functions of standards development and research.

The committee acknowledges that there could be some disruption as a result of such a change. However, the committee judges that on balance the price may be worth paying.

DESIGNING THE SAFETY RESEARCH PROGRAM AND FOLLOWING THROUGH

Designing a program of nuclear safety research is necessarily a complicated, ceaseless, evolutionary process with a number of central features. The program should be designed through a process that includes the following:

- establishing a research philosophy,
- developing and implementing long-range strategies,
- setting near-term priorities, and
- coordinating with others in the design and use of the program.

The last of these is as critical as the other three. To design an effective program, the Office of Research must consult with users of research both inside and outside the agency, including in the former case the Office of Nuclear Reactor Regulation and the commissioners. Coordinating with these various parties is especially important in the design of the program because it is only through this process that the agency's research philosophy, long-range goals, and research priorities can be integrated into a cohesive program. It is at this step in the process that the program will succeed or fail to achieve direction.

Establishing a Research Philosophy

A program of safety research cannot be properly designed without a research philosophy that supports the mission of the agency to guide it. Yet the current NRC research program appears to lack such a philosophy. Developing such a philosophy is a difficult undertaking, but it is one of the primary responsibilities of the Commission. There cannot be five separate philosophies for the agency, one for each commissioner, without wreaking havoc on the research program. The program requires a consensus philosophy that gives direction to research planning, and that provides a framework on which the program can be built, guidelines for establishing priorities and focusing the research effort, and criteria with which to assess whether a given area of research is continuing to serve a useful purpose.

For these reasons the committee recommends:

3. The NRC should develop a cogent research philosophy that can be used to direct and assess the effectiveness of the safety research program. If the Commission is unable to reach agreement on a research philosophy, then the chairman must develop one on his or her own.

An appropriate philosophy of safety research would make clear that the agency has a commitment both to the continuing review of knowledge gained from operating reactors and from ongoing research and to the revision of existing safety regulations in light of that experience.

An example of one of the benefits of having a research philosophy is that such a philosophy would make clear what organizing principle or principles are being used to construct the program of research, for example, what determines the balance between research on accident prevention and research on accident mitigation.

While at a policy level the Commission and Congress need to determine how safe is safe enough, at the research level the philosophy must be that sufficient information is available to assure that policy decisions are made on the basis of the best available knowledge. Thus, research that is wholly focused on supporting existing or proposed regulations would too narrowly circumscribe the research mission by ignoring the broader need to acquire knowledge to identify and anticipate the unexpected. Similarly, research that tends to challenge existing wisdom about nuclear plants—either suggesting the need for more or less regulation—cannot be restricted or kept from the public eye merely because such information may be used by others to urge the Commission to alter its regulations or otherwise change its view of how safe is safe enough.

In the fullest sense a sound research program is apolitical and must be committed to the principle of full and complete information. Once such a philosophy is established, the research program can and should rise above the political fray.

Developing and Implementing Long-Range Strategies

Each year since 1981 the Office of Research has issued a long-range plan. Previously the office occasionally issued planning documents as part of the so-called "Rainbow series" of regulatory activity reports. The principal function that the current long-range plan seems to serve is simply to force interaction between the Office of Research, the other user offices, and the ACRS. Some coordination occurs because of the existence of this mechanism, but it seems almost incidental to the plan itself. The NRC long-range plan is not really a plan so much as a description of current projects. So although many "long-range plans" have been written, there is little long-range planning. (This happens to be true not only at the NRC but within the federal government as a whole.) The purpose of long-range planning ought to be to instill in the entire program a sense of its long-range strategies for implementing the agency's research philosophy. It should clarify the connection between the research philosophy and the various elements of the annual budget, but it has no value if it does nothing more than recount what that budget consists of. In fact, the process is likely to be more important than whatever plan may emerge from it. The point of the exercise is to engender a discussion of the connection between the organizing principle(s) for research and the structure of the future program.

For these reasons the committee recommends:

4. The NRC should establish a research program planning process involving all of the relevant offices within the NRC, as well as representatives from industry and the university research community acting as participating advisors. The line responsibility for planning should rest with the director of research.

The resulting process can be used to deal with some of the problems discussed below concerning coordination with the user community and other sponsors of research.

Setting Priorities (Developing an Annual Budget)

The fact that there is virtually no human factors research within the current annual budget of the Office of Research, in spite of the clear indication that research in this area is vital to assuring the safety of operating reactors, indicates that something is seriously wrong with the way the agency goes about structuring its program and setting its budget priorities. As noted above, the current process shows little indication of being connected to either a research philosophy or a long-range strategy of research. The annual review of the budget ought to be logically related to a long-range strategy for implementing the research philosophy. Effective management of the overall program and effective planning of the annual budget require that the Office of Research review the logic of specific program elements. This should be accomplished through a process that involves interacting with four different groups: the user community within the agency (including the other program offices, the Advisory Committee on Reactor Safeguards, and the commissioners); other sponsors of research; an independent group of expert advisors to the Office of Research; and the oversight bodies within the executive branch and the Congress. The annual program that emerges from these interactions should be consistent with the agency's long-range strategy for implementing its research philosophy, and it should reflect a consensus on the appropriate priorities for achieving the objectives embedded in that philosophy. There are important management issues that must be addressed in order to establish proper working relationships between the Office of Research and these four groups. The health of these relationships is vital to the health of the research program as a whole.

Coordinating with the User Community

In the present context, the user community includes the other program offices (Office of Nuclear Reactor Regulation, Inspection and Enforcement, Nuclear Materials Safety and Safeguards), the Advisory Committee on Reactor Safeguards (ACRS), and the commissioners. Unless there is a strong working relationship between the Office of Research, on the one hand, and these other bodies on the other, particularly between the Office of Research and the commissioners, there is little reasonable chance of having a sound research program. A strong working relationship must be developed and sustained in both the planning and the use of the research program.

Coordinating with Other NRC Program Offices. Coordinating with the other program offices, particularly with the Office of Nuclear Reactor Regulation (NRR), serves two important functions: to communicate the results of research to those who need it and to refine the design of the program in order to take into account the needs of the user community.

Although the existing relationship between the Office of Research and NRR may be formally correct, with formalized arrangements for interoffice concurrence, the transmission of user request memoranda, and the distribution of research reports, in reality there is insufficient substantive interaction at the level and with the continuity and intensity that is needed for a used and useful research program. In fact, there seems to be little interest in or understanding of the existing research program outside of the Office of Research.

In principle, the results of NRC research should be used in regulation, and most (but importantly not all) research should be aimed at solving present or anticipated regulatory problems. This requires a close working relationship between NRR and the Office of Research. However, as noted above, the Office of Research and NRR do not work together effectively, merely formally.

The view from NRR is that although the Office of Research sponsors a lot of work, it does little to integrate the results of that research. It does not package it in a form that is useful to NRR or that brings home the significance of the work to the potential user. Research Information Letters (RILs) are supposed to serve this function and are still being written by the Office of Research, but apparently these are either unread or not useful. In any case, while formal synthesis documents have a place, they cannot substitute for continuing dialogues about the evolving plans for and results of the research program.

The view from outside the agency is equally critical. The national laboratories complain that not enough integration occurs between NRR and the Office of Research. The industry often appears to be confused by the constant turf battles between the Office of Research and NRR.

There is a natural tension between managers of research and those who regulate; it is a variety of the traditional tension between researchers and those charged with applying research. However, what the committee found goes well beyond that and reflects a serious problem within the agency in the management of the relationship between agency users and the Office of Research. In an effective working relationship, the potential users respect the role of the researchers as technical critics, and the user community is intensely involved in setting the research agenda.

It is important to note that the NRC needs both formal and informal mechanisms to involve regulators in setting the research agenda, to coordinate research undertaken by the Office of Reseach and technical assistance undertaken by NRR, and to encourage face-to-face discussions of NRR's needs and the Office of Research's programs and results. NRR must have enough competence to understand the technical information available from the Office of Research; and both parties must work together to understand how research results should be applied. What the committee has in mind is a process in which staff at the branch level in NRR and in the Office of Research regularly (at least weekly) meet for an hour or two to informally exchange information about what is happening in each other's areas of responsibility. Each must be able to understand the basic substance and keep track of the progress of the other's work. It is only through this type of constant communication and discussion that some technical transfer takes place; and it is only through such contact that the regulator can effectively assist in setting the research agenda.

The committee recommends:

5. The executive director of operations should ensure that much more face-to-face discussion occurs among the NRC program offices at the branch level concerning the philosophy and content of the research program.

Utilization of the products of the research program would be facilitated if NRC initiated a practice of drafting interoffice documents on regulatory issues, with the Office of Research actively participating. These reports should summarize what is known about a particular question and what research is still needed and why. The purpose of these reports would be to assist standard setting and regulation by reaching conclusions on open issues. In addition, these documents would provide guidance to the future research program.

Hence, the committee recommends:

6. The NRC should adopt the practice of producing interoffice documents that summarize what is known and what research is still needed, and that reach conclusions about regulatory issues. The Office of Research should play an active part in the preparation of such documents.

Coordinating with the Advisory Committee on Reactor Safeguards. Because the Advisory Committee on Reactor Safeguards (ACRS) has a statutory role in reviewing applications for nuclear power plant licenses, its institutional relationship to the Office of Research is that of a user office. Congress has intervened in that relationship for the apparent purpose of using the ACRS as an independent research advisory group. Thus for the last five years the ACRS has been formally responsible for evaluating the NRC research program on an annual basis and providing comments on the program both to the Commission and to the Congress. In order to conduct these reviews the ACRS established a subcommittee that annually hears from members of the research staff. These hearings form the principal bases of the ACRS report. The ACRS reviews have had no apparent impact, and Congress no longer seems to use them. The ACRS has itself asked Congress to relieve it of the obligation to continue to provide them. In the past, the ACRS role was less formal; it simply provided whatever comments it had on the research program whenever it saw fit. Congress should understand that because ACRS is constituted to review license applications it is not properly structured to serve as an independent research advisory group. Active licensee representatives should, however, be part of such a group; although precluded by Commission policy from serving on the ACRS, they can be valuable participants as major users and performers of research.

The committee recommends:

7. The Congress should relieve the ACRS of any formal requirement to review the safety research program.

Nonetheless, the ACRS contains a substantial amount of expertise on nuclear safety and the Office of Research should continue to coordinate informally with the ACRS or a designated ACRS subcommittee in designing the research program. As research issues arise in the course of reviewing license applications, the ACRS should continue to recommend appropriate avenues of research to the NRC chairman, and the chairman should ensure that the Office of Research gives them serious consideration.

Coordinating with the Commissioners. It would come as a surprise to almost anyone who was unfamiliar with the management of the NRC how little coordination occurs between the Office of Research and the putative head of the agency, the Commission. In theory the five commissioners manage the agency and the agency staff, yet in practice they do little policy formulation, program planning, or staff guidance and do not appear to understand the program as it now exists. This is one of the principal reasons why the research program lacks adequate direction.

It became obvious to the committee that the issue of managing safety research is really part of the larger issue of managing the agency. Establishing a research philosophy for planning research, identifying and correcting weaknesses in research management, holding the research director accountable—these are basic functions of the head of any agency that conducts research. Yet the commissioners do not now provide this leadership. The structure of the Commission and the somewhat self-imposed constraints under which the Commission operates seem to make it impossible for it to carry out the intense, interactive, critical, and self-critical, communication with the staff, advisory groups, other research sponsors, and among the commissioners themselves that is required in order to formulate, execute, and use the results of a first-rate research program. The essence of what is needed is intense, informal, sometimes combative communication—both within the agency and with those outside who can help shape the program. The current mode of operating has the effect of preventing just such communication, and thus preventing the development of a research program that makes real and obvious contributions to safety.

The research management problems that the committee has found might stand a better chance of being resolved were there a single administrator with management responsibility for the NRC. The committee hastens to add, however, that it has not fully considered all the ramifications of moving to a single administrator; such a step would encompass a much broader set of issues than merely how to manage research more effectively. The committee is equally aware that a single administrator would not necessarily be better; it depends on the person.

The committee therefore recommends:

8. Options for restructuring the NRC to restore leadership to nuclear safety research at the NRC should be reexamined.

A reexamination of the kind needed is beyond the scope of the NRC, and is something for Congress and the administration to consider.

Restructuring the agency in any significant way is a major step that would require congressional action. In lieu of that, and given the fact that the research program constitutes almost a third of the NRC budget, the committee recommends that the following steps be taken:

9. The NRC chairman should assign a member of his or her staff to devote full time to monitoring research, including visiting researchers, talking with the Office of Research personnel, and sitting in on all meetings devoted to research in order to keep the chairman informed.

In particular, if the ACRS continues to review formally the safety research program, this person should attend all ACRS subcommittee and committee meetings leading up to the ACRS report on the research budget. This is essential in order to be able to interpret the ACRS report.

The committee recommends:

10. The chairman should require periodic review of the status of major research projects.

This will provide a mechanism for determining whether projects are completed, whether knowledge and technology should be transferred to a user, or whether and what further research is needed.

Finally, the committee recommends:

11. The chairman should develop an understanding of the research program and then personally defend the program before OMB and the Congress.

Successful defense before OMB and the Congress requires battle by a knowledgeable agency head. It cannot be delegated to subordinates.

Coordinating with Sponsors and with Those Who Do Research

The agency needs to coordinate its program not only with the user community within the agency but also with others who sponsor and perform research, including the contract research community, the national laboratories, industry, DOE, and perhaps other federal agencies when appropriate. Currently there is far too little coordination or interchange between NRC and DOE in the area of nuclear safety research. However, cooperation is not just an NRC responsibility; DOE can and should do more on its own initiative.

The committee recommends:

12. Both DOE and NRC should collaborate to establish institutional mechanisms for periodically sharing appropriate results of their respective programs of nuclear safety research, including any applicable results from the naval reactor and defense production reactor programs.

Establishing an Independent Research Advisory Group

The NRC needs a formal mechanism for acquiring external advice on the philosophy, management and content of its research program.

The committee therefore recommends:

13. The NRC should empanel an independent advisory group, reporting to the director of research, with expertise in the range of disciplines relevant to nuclear safety research.

The group should be charged with independently reviewing for the director of research, from the perspective of the general principles cited in this report, the overall structure and thrust of the research program. The group should consist of members drawn from the contract research community (including the universities) and from industry. Involving industry increases the probability that the group will ask some tough yet important questions, including "Is the benefit worth the cost?" Involving industry will also require viewing industry as adversarial partners, rather than merely as adversaries. Selection of the membership of the advisory group should be based on scientific and engineering competence and should provide breadth of coverage across the major categories of nuclear safety research. The group should reflect a balance of views in order to minimize bias.

Establishing Peer Review

Unless this independent research advisory group has confidence in the quality of the work that the agency is sponsoring, the NRC will not be able to gain the benefits that a such a group could provide. The traditional means by which the scientific and engineering communities ensure the quality of research is through peer review. The most effective mechanism is for the agency to establish independent topical peer review groups and to encourage the publication of sponsored research in peer-reviewed technical journals. Peer review would be highly beneficial even if there were no advisory group, because it would foster confidence in the products of NRC research and help maintain high standards of competence in the program.

The committee therefore recommends:

14. The NRC should establish independent topical peer review groups and encourage the publication of sponsored research results in peer-reviewed professional publications. These independent review groups should be charged with reviewing all research products of NRC-sponsored research.

Some areas of research are sufficiently complex (e.g., large-scale scientific modeling and major experiments) that it is not reasonable to expect volunteers charged with peer reviewing the work to be able to ensure quality. In such cases adequate peer review requires the provision of adequate funds to the peer reviewers. Though peer review is no panacea for the range of structural and other problems currently burdening the safety research program, lack of peer review is an obstacle to the design of a meaningful program and undermines the confidence in the research of intended users, both regulators and regulated alike.

CONTRACTING FOR SAFETY RESEARCH

One of the primary responsibilities of the director of research is to select researchers capable of doing a good job in performing the research that the agency needs to have done. The director must establish policies and procedures governing the contractor selection process, including procedures that permit the agency to keep track of a wide range of scientific and engineering disciplines, to know who is conducting research in various fields and to develop an awareness of their availability to the agency. The director must also ensure that the office establishes a rigorous process for acquiring and factoring into the selection process independent appraisals of the quality of the work being completed by agency contractors.

There are two basic characteristics of the way the NRC has tended to allocate research among potential contractors: heavy reliance on the national laboratories and minimal support of university research.

Contracting with the DOE National Laboratories

From 1975 to 1981 the budget for safety research at the NRC expanded fourfold (in current dollars), partly in response to the accident at Three Mile Island. But in the last five years that trend has turned around and the budget has been progressively cut to where it stands today—half of what it was in 1981. In real buying power the downturn has been even more precipitous. The reduction in funding has been accompanied by substantive changes in the overall program. Nonetheless, NRC contracting patterns have remained basically the same as they were in 1975 when the agency was formed—overwhelmingly concentrated in the national laboratories. NRC contracting has been strongly influenced by circumstances surrounding the birth of the agency; the NRC was, of course, created out of parts of the Atomic Energy Commission, which had charge over the national laboratories that conducted the bulk of the AEC's safety research. Congress precluded the newly established NRC from building its own research facilities and directed the agency to make use of ERDA's (now DOE's) national laboratories. Not surprisingly, therefore, the new NRC came to rely heavily on the national laboratories for the performance of its safety research.

The committee is concerned that a valid basis for contracting nearly all of the safety research program through the national laboratories does not exist. The committee concluded that a fair competition among the national laboratories, industry, and the university research community might lead NRC to allocate a larger share of its research to private industry and to contract researchers in the universities.

Hence, the committee recommends:

15. The NRC should create a fair and competitive process for allocating research among national laboratories, industry, and contract researchers including the universities.

It is important to note that Congress made a similar request of the NRC in the past but with little effect.

This is not to suggest that the national laboratories do not do high-quality work. They have made substantial contributions to nuclear reactor safety, and can continue to provide not only unique facilities for conducting safety research but a staff that includes some of the most highly competent research scientists and engineers in the world. However, the NRC program's current and previous heavy reliance on these laboratories for more than 80 percent of the work does not appear to be the result of conscious decisions that all of the best people are there or that all of the most important proposals come from the laboratories. The committee concluded that NRC reliance on the laboratories has been carried over from the AEC primarily because of (1) the great ease of transferring funds to federal laboratories as compared with contracting with other research institutions such as industry and the universities, (2) the availability of experimental facilities and qualified research personnel, and (3) the ease of avoiding any appearance of conflict-of-interest, which might result from greater reliance upon industry. Little effort appears to have been expended by the Office of Research to create a truly fair and competitive process for selecting performers of NRC research.

The committee recommends:

16. The NRC should charge its contract office to develop procedures to make research contracting with organizations other than the national laboratories an easily available option, not one requiring many months of voluminous paperwork.

The committee knows from its own experience that federal regulations have provisions that allow *research* contracts to be let without using only the most cumbersome and time-consuming procedures in the federal procurement process. The contract offices of other major federal funders of research would be good sources of advice in identifying these provisions.

The NRC is obligated to use the best contracting procedures that the Congress has made available, but it has not been doing so. In most cases the NRC responds to research proposals from university researchers by initiating formal, open competitive bidding.

However, industry and the universities have profoundly different organizational structures, so much so, in fact, that industry-based and university-based researchers cannot actually compete fairly against one another in competitive bidding situations.

On occasion, the NRC has managed to avoid utilizing competitive bidding by directing university researchers to go to a particular national laboratory that has a research contract with the NRC, and in turn directing the laboratory to let a subcontract with the university researcher. This practice is of dubious legality and is resented both by the laboratories and the university research community since it turns research managers at the laboratories into middlemen and inserts an unnecessary and burdensome layer of management and bureaucracy between the university faculty member and the sponsor of the research.

The NRC is currently considering ways to consolidate work at the national laboratories. In particular, the NRC has decided to consolidate thermal hydraulics research at the Idaho National Engineering Laboratory.

The committee recommends that the NRC go further:

17. The NRC should conduct a careful analysis to weigh the relative costs and benefits of various options for consolidating work at the national laboratories.

The plan to phase out the large experimental facilities makes consolidation more feasible. Consolidation might have the benefit of increasing laboratory management attention on NRC programs and might provide a stronger overall corps of researchers both inside and outside the laboratories. Congress might even consider reconstituting one or more of these laboratories as a completely joint government-industry center for nuclear safety research, perhaps modeled to some extent after the Health Effects Research Institute, which is run jointly by industry and the Environmental Protection Agency.

The managers of NRC programs at the various national laboratories seldom meet to discuss the philosophy, content, and direction of the NRC research program. This means that the laboratories have little opportunity to assist in the design of the program.

The committee recommends:

18. The NRC should institute at least an annual review of the program with the principal performers of research, including but

not limited to representatives of the national laboratories, EPRI, and managers of other major pieces of the research program.

This will help the laboratories understand where their projects fit into the program and will give the NRC the benefit of advice from knowledgeable research managers.

Contracting with the Universities

In the previous section the committee recommended reevaluating the amount of reliance on the national laboratories for nuclear safety research. Industrial laboratories and other members of the contract research community have competent staffs and should be used when they are best qualified to do the work. Universities can also be relied on to do significant research. Yet in the recent past the universities have received inadequate support from the possible sources of funding for nuclear safety research—industry, DOE, the NRC, and the National Science Foundation (NSF). NSF support for nuclear engineering has been reduced to approximately half a million dollars, of which only a fraction is related to nuclear safety. NRC support for university research is a little over $3 million but this is one third what it was five years ago.

As previously noted, university research has some clear benefits. The universities provide a source of independent thinking as well as "centers-of-excellence" in basic and exploratory research. Dedicated long-term funding of university researchers must be available to ensure retention of a corps of experienced academic researchers in basic science and engineering and to provide a training ground for the future nuclear safety research professionals that will be needed to staff industrial laboratories, contract research organizations, and government agencies.

The NRC has indicated that university-based research is highly cost-effective. However, the NRC apparently has had difficulty using the universities, in part because of the contract problems discussed earlier and in part because strong links have not been sustained between the universities and the NRC.

The committee recommends:

19. The NRC should request that Congress expand NRC's grant authority and then NRC should award more money to universities as grants, rather than as contracts.

The committee also recommends:

20. The NRC should encourage and assist university faculty to do nuclear safety research at the national laboratories.

Though it is already possible for university researchers to conduct research at the national laboratories, the NRC and the DOE have not encouraged researchers in the field of nuclear safety to do so. This is why university faculty seldom use the national laboratories for nuclear safety research, which is in marked contrast to the high-energy physics community where faculty routinely perform experiments using federal facilities designed for high-energy physics research.

Even if the recommended expansion of grant authority is not implemented, the NRC should use its existing grant authority more aggressively.

The committee recommends:

21. The NRC should establish a competitive grant program, using peer review panels for selecting grant recipients.

22. The NRC should assign a staff member the task of overseeing university research funding.

DOE plans in FY 1986 to increase support for university-based nuclear research from a little over $2 million to about $6.6 million.

The committee recommends:

23. The Department of Energy should ensure that a portion of its budget for university-based nuclear R&D goes to support safety research of relevance to current reactors.

COMMUNICATING WITH THE OFFICE OF MANAGEMENT AND BUDGET AND WITH THE CONGRESS

Once a program is designed, the agency must convince OMB and the Congress that its design is sound. A sound research program must be based on a safety research philosophy, a long-range strategy, and a set of near-term priorities, with the priorities linked to the philosophy and strategy in some transparent and meaningful way. It must also have stable funding. This does not mean a guaranteed level of funding, but it does mean sufficient funding committed over a long enough period of time to permit the closure of individual program elements. Constantly changing levels of support, particularly constantly declining levels of support, cripple a research program. They undermine basic and exploratory research, which tend to get squeezed out in favor of short-term needs. And they destroy researcher and staff morale.

The NRC is understandably concerned about the continuing reduction in funds for the agency generally and for nuclear safety research in particular. While the Advisory Committee on Reactor Safeguards has repeatedly warned that the continuing erosion of support is jeopardizing the viability of the safety research program, it has been unable to say what would be an appropriate level of funding for nuclear safety research. The committee finds itself in a similar position. It has received estimates from senior NRC staff ranging from the view that the current level of funding is "grossly inadequate" to the view that there probably is a little fat in the program even at current levels. The committee has concluded that it is in no position to say what the right number is or to recommend a specific amount for NRC research.

The committee cannot fail to note, however, that the erosion in support for the NRC budget is in this case indicative of a much more substantial problem: the lack of meaningful communication between NRC and OMB and NRC and the Congress. The OMB and the Congress have shown little understanding of or support for the NRC program. The responsibility for this problem lies on both sides. On the one hand, the NRC program is in dire need of reform. By failing to achieve closure of safety issues and thus by denying itself the opportunity to explain fully the role of research in leading to closure, the NRC undermines congressional and administration support. The NRC's failure to use the research program properly to help close outstanding safety issues prevents the Congress and the OMB from playing a constructive role in overseeing the planning and implementation of the research program. On the other side, OMB refuses to recognize the ramifications for nuclear safety research of continually cutting the NRC budget. And Congress is torn between those who want the safety research program to produce tighter constraints on the nuclear power industry and those who look to research to relax the existing regulations. The division in Congress, of course, mirrors national attitudes toward commercial nuclear power; yet merely passing these along to the NRC, without resolving them, exacerbates the agency's difficulties in establishing and maintaining an effective program of research.

Nuclear safety research is too important to be continually whipsawed and debilitated by bad management and the vicissitudes of the political process. It requires competent, responsible leadership from OMB and the Congress, as well as from NRC.

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Appendix A
Sponsors of Commercial Nuclear Research and Development

This Appendix provides a brief overview of the programs of the major sponsors of nuclear research in both the public and private sectors. The discussion principally centers on the programs of the NRC, the DOE, and the electric utility industry.

GOVERNMENT SPONSORSHIP OF NUCLEAR RESEARCH

The majority of the nuclear safety research funded by the federal government is sponsored by the NRC. Statutory responsibility for the NRC's research program, funding for which in fiscal year 1986 will be about $108 million, resides with the Office of Nuclear Regulatory Research. A small amount of safety research is also conducted by other NRC program offices. For example, the Office of Nuclear Reactor Regulation (NRR) funds about $30 million of "technical assistance," of which the committee estimates at least $10 million is safety research.

The NRC's budget for nuclear safety research is slightly more than half of what DOE will spend in FY 1986 on civilian nuclear R&D. However, the entire NRC program is safety research in support of current reactors, whereas DOE's program is principally aimed at the development of advanced reactors. There have been significant reductions in congressional appropriations for NRC research over the past five years; so although in current dollars the program is twice the size it was a decade ago, it is less than half what it was at its peak in 1981. In terms of true buying power (i.e., constant dollars), the reductions have been even more dramatic.

Tables A.1, A.2, and A.3 present figures on the NRC research program in each of three years: FY 1975, the year the NRC was established; FY 1981, at the height of NRC spending for research; and FY 1986, planned spending for the current fiscal year.

The figures for FY 1975 clearly show that the entire $52 million program was dominated by research on thermal hydraulics and accident evaluation. At that time this research focused primarily on the analysis of large-break, loss-of-coolant accidents. In order to conduct realistic experiments testing the adequacy of emergency cooling systems to cope with loss-of-coolant accidents, the NRC had previously decided to build a Loss-of-Fluid Test (LOFT) facility at the Idaho National Engineering Laboratory, and by FY 1975 spending on LOFT had already begun. Over the next decade, LOFT was the single most expensive component of the entire NRC research program. As early as 1975, Idaho accounted for about 40 percent of NRC's research dollars.

The figures for FY 1981 reflect the growth in spending on LOFT over the previous six years. Between 1975 and 1981, contracts awarded to Idaho quadrupled, in step with the overall quadrupling in current dollars of the NRC research program, which by 1981 had risen to $209 million. Five years later, however, these trends were completely reversed. Data on planned expenditures for 1986 show the effects of the intervening decision to terminate LOFT; NRC contracts to be awarded to Idaho have plummeted from 39 percent of the total in 1981 to less than 18 percent of the program in 1986.

The NRC research program has been in transition since the late 1970s. The transition has been away from research on large-break, loss-of-coolant accidents toward more complex types of accidents. A larger share of the NRC program is now devoted to understanding the transportation of fission products and the integrity of reactor containments during core melt accidents. The principal catalyst for the change in approach was the accident at Three Mile Island.

A comparison of NRC's actual spending for research in FY 1981 with the program planned for FY 1986 indicates how the NRC has accommodated the 50 percent reduction in support it has received over the past five years. The reduction was absorbed by sharply cutting back on thermal hydraulics and accident evaluation research (terminating LOFT and reducing the level of research at other experimental facilities), by canceling all NRC research on

TABLE A.1 FY 1978 Allocation of NRC Research Contract Dollars by Decision Unit (thousands of 1975 dollars)

—	Reactor Engineering	Thermal Hydraulics	Accident Evaluation	Reactor Operations and Risk	Waste and Health	Advanced Reactors	Totals
U.S. government	1,907	15,750	15,760	765	1,137	4,291	39,610
National laboratories	1,707	15,715	15,735	735	127	4,291	38,310
Argonne	0	582	140	0	0	360	1,082
Brookhaven	0	485	0	0	0	1,271	1,756
Idaho	0	8,908	12,965	0	0	0	21,873
Lawrence Berkeley	0	0	0	0	77	0	77
Lawrence Livermore	0	0	0	0	0	0	0
Los Alamos	0	450	100	0	0	1,935	2,485
Oak Ridge	1,707	1,990	1,760	435	0	200	6,092
Pacific Northwest	0	3,300	585	0	0	0	3,885
Sandia	0	0	185	300	50	525	1,060
Other U.S. government	200	35	25	30	1,010	0	1,300
Universities	126	102	38	24	225	200	715
Private sector	864	1,165	826	219	428	65	3,567
Foreign	0	666	0	0	0	0	666
State governments	0	0	0	0	10	0	10
Undesignated	3,317	2,134	792	1,084	293	748	8,368
TOTALS	6,214	19,817	17,416	2,092	2,093	5,304	52,936

TABLE A.2 FY 1981 Allocation of NRC Research Contract Dollars by Decision Unit (thousands of 1981 dollars)

	Reactor Engineering	Thermal Hydraulics	Accident Evaluation	Reactor Operations and Risk	Waste and Health	Advanced Reactors	Totals
U.S. government	25,879	29,220	81,948	24,777	15,504	9,390	186,718
National laboratories	23,092	29,145	81,783	24,437	11,944	9,390	179,791
Argonne	2,183	1,000	125	280	1,606	990	6,184
Brookhaven	1,059	2,243	810	1,510	2,164	1,840	9,626
Idaho	1,578	18,815	57,154	3,769	140	0	81,456
Lawrence Berkeley	0	0	90	0	85	0	175
Lawrence Livermore	4,364	0	296	1,702	566	0	6,928
Los Alamos	957	3,935	2,385	1,909	390	2,260	11,836
Oak Ridge	4,182	2,077	7,545	4,379	1,896	275	20,354
Pacific Northwest	5,218	800	5,582	3,448	4,175	150	19,373
Sandia	3,551	275	7,796	7,440	922	3,875	23,859
Other U.S. government	2,787	75	165	340	3,560	0	6,927
Universities	839	1,194	117	142	6,391	242	8,925
Private sector	2,200	885	5,037	2,905	1,478	80	12,585
Battelle	307	107	677	823	0	0	1,914
Westinghouse	0	0	1,800	0	115	0	1,915
General Electric	108	0	1,825	0	0	0	1,933
Foreign	0	490	0	5	326	45	866
State governments	0	0	0	0	386	0	386
Undesignated	3	0	1	0	0	0	0
TOTALS	28,921	31,789	87,103	27,829	24,085	9,757	209,484

TABLE A.3 FY 1986 Allocation of NRC Research Contract Dollars by Decision Unit (thousands of 1986 dollars)

	Reactor Engineering	Thermal Hydraulics	Accident Evaluation	Reactor Operations and Risk	Waste and Health	Advanced Reactors	Totals
U.S. government	32,825	14,146	27,545	13,625	5,897	0	94,038
National laboratories	31,365	14,146	27,545	13,626	4,147	0	90,828
Argonne	4,045	240	1,315	0	510	0	6,110
Brookhaven	2,405	400	2,040	2,405	945	0	8,195
Idaho	3,600	7,856	5,180	2,455	250	0	19,341
Lawrence Berkeley	0	75	0	0	840	0	915
Lawrence Livermore	1,300	0	0	310	0	0	1,610
Los Alamos	1,200	4,636	950	700	0	0	7,485
Oak Ridge	7,400	500	3,955	825	405	0	13,125
Pacific Northwest	4,770	15	3,155	1,150	672	0	9,762
Sandia	6,605	425	10,950	5,780	525	0	24,285
Other U.S. government	1,460	0	0	0	1,750	0	3,210
Universities	0	434	0	50	2,583	0	3,067
Private sector	5,402	2,890	1,140	431	1,533	0	11,396
Battelle Columbus	1,900	0	1,140	0	500	0	3,540
Babcock & Wilcox	0	2,425	0	0	0	0	2,425
Materials Engineering	2,150	0	0	0	0	0	2,150
Other	1,352	465	0	431	1,033	0	3,281
Foreign	0	0	0	85	175	0	260
State governments	0	0	0	0	75	0	75
Undesignated	0	0	0	0	50	0	50
TOTALS	38,227	17,470	28,685	14,191	10,313	0	108,886

advanced reactors, and by reducing both the number and kind of projects in the area of waste management, earth sciences, and radiological health effects research. Meanwhile, support for severe accident research and research on risk assessment was increased. Risk assessment research, for example, doubled between 1981 and 1986.

Sandia National Laboratories, located in Albuquerque, New Mexico, has become the NRC's principal research contractor. Sandia's program of NRC-sponsored research centers on analytical and small-scale experimental studies of severe reactor accidents. Over the first half of the 1980s, Sandia's level of NRC-sponsored research remained at about $24 million at a time when the NRC research program as a whole was being subjected to a 50 percent cut. As other projects and contractors were being cut back, Sandia's share of the NRC research program climbed to 20 percent.

Table A.4 indicates that despite severe fluctuations in NRC funding over the agency's first decade, the pattern of NRC contracting—the percentage of research allotted to government, universities, and the private sector—has remained fairly constant; the vast majority of NRC funds continue to go to federal laboratories. This long-term consistent pattern of contracting, when coupled with a steep decline in available funds, has meant a significant drop in the level of NRC research performed by the universities. Although it is the committee's impression that, in the last few years, NRC spending for university research has increased modestly, the five-year trend shows a reduction of two-thirds—from 4.3 to 2.9 percent of the budget. A close examination of the planned FY 1986 program shows that most of the research that NRC plans to sponsor in universities consists of relatively small amounts aimed at funding university operation of seismic monitoring stations throughout the eastern half of the United States. These are programs that the NRC recently has said are candidates for transfer to the U.S. Geological Survey, a move that would further diminish the level of NRC support for university research.

While this report focuses primarily on the NRC, it should be noted that substantially more of the amount spent by the federal government on civilian nuclear power is spent by the DOE than by the NRC. However, DOE spends the greatest part of its civilian nuclear R&D money on development, not on safety research. DOE will spend approximately $182 million for civilian nuclear R&D in FY 1986. In addition, DOE has large programs in uranium

TABLE A.4 Allocation of NRC Research Contracts by Sector

	Percentage of Designated Contracts		
	FY 1975	FY 1981	FY 1986
U.S. government	88.9	89.1	85.7
national laboratories	(86.0)	(85.9)	(83.4)
Universities	1.6	4.3	2.9
Private sector	8.0	6.0	10.4
Other	1.5	0.6	1.0
TOTALS	100.0	100.0	100.0

enrichment, naval propulsion reactors, and high-level radioactive waste management, each of which is larger in scale than the NRC program of safety research.

Table A.5 shows how DOE intends to allocate the $182 million available in FY 1986 for civilian nuclear R&D and how this sum is meant to be distributed among the five programs within the department devoted to that effort (Light Water Reactor Safety and Technology; Regulatory Development; Plant Performance; Advanced Converter Reactors; and Technology Development). Table A.5 indicates that DOE has allocated only about $50 million for light-water reactor safety. Furthermore, most of that amount is aimed at supporting the decommissioning of the LOFT facility and the removal and analysis of the damaged Three Mile Island reactor core.

Table A.6 provides a different perspective on the DOE program by dividing it into research on current light-water reactors and research on future reactors. The table also provides greater detail on how the $182 million is allocated: at least 70 percent of the DOE program is directed at advanced reactor R&D; 16.5 percent will fund the continuing cleanup at Three Mile Island; and 5 percent will fund the cleanup of the LOFT reactor in Idaho. Very little of the remaining 9.5 percent of DOE's civilian nuclear R&D budget for FY 1986 directly supports current reactors, and even less goes for safety research.

TABLE A.5 Allocation of DOE Contracts by Program (thousands of dollars)

	LWR Safety and Technology	Regulatory Development	Plant Performance	Advanced Converters	Technology Development	Totals
U.S. government	43,691	200	1,460	72,471	0	117,822
National laboratories	43,291	200	1,460	50,056	0	95,007
Argonne	350	0	40	26,662	0	27,052
Brookhaven	0	0	0	0	0	0
Idaho	42,036	0	0	564	0	42,600
Lawrence Berkeley	0	0	0	0	0	0
Lawrence Livermore	0	0	0	0	0	0
Los Alamos	0	0	0	993	0	993
Oak Ridge	150	0	1,420	943	0	1,093
Sandia	755	200	0	74	0	1,029
Other U.S. government	400	0	0	22,415	0	22,815
Universities	0	0	0	0	6,600[a]	6,600
Private sector	7,309	0	0	50,013	0	57,322
Foreign	0	0	0	0	0	0
TOTALS	51,000	200	1,460	122,484	6,600	181,744

[a] Estimate (grants not yet awarded).

TABLE A.6 Allocation of the 1986 DOE Research Program by Reactor System[a] (thousands of dollars)

	Future Generation Reactors					
1. Current LWRs	2. Advanced LWRs	3. Advanced LMRs	4. HTGRs	5. Breeders	6. Both[b,c]	7. Other
745	8,996	30,909	28,700	50,107	34,760	20,727

Projects included in each of the above categories:

1. plant life extension; plant availability
2. advanced reactor assessment; ALWR assistance; advanced LWR (EPRI program), advanced LWR; pool plant design and evaluation
3. advanced concepts development; power conversion technology development, nuclear systems technology development
4. HTGR fuels and materials testing, design and licensing
5. breeder components development; fuel performance and supply; reactor core development; breeder fuel cycle development
6. extended burnup of LWR fuel; source term; technology management center, STEP; LOFT (postirradiation fuel examination); Three-Mile Island; risk-based licensing
7. LOFT cleanup; international nuclear policy and program; nuclear/fossil power plant economics, costs; economic regulation; institutional issues; constructibility; safeguards; research/test reactor fuel demonstration

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[a] Includes the following divisions under the assistant secretary for nuclear energy: LWR safety and technology; regulatory development; Plant performance; and advanced converter development.

[b] Potentially applicable either to current or future reactors or to both.

[c] May be applicable to current and future reactors.

PRIVATE SECTOR SPONSORSHIP OF NUCLEAR RESEARCH

Because of proprietary restrictions on access to data, the committee is unable to estimate accurately the current scale of safety research sponsored by U.S. reactor vendors (Babcock and Wilcox, Combustion Engineering, GA Technologies, General Electric, and Westinghouse); it is believed to be in the tens of millions of dollars. The committee has no estimate at all of the R&D conducted by nuclear suppliers (e.g., pump and valve manufacturers), but it assumes that the amount is relatively limited, particularly when compared with the amount of R&D sponsored by reactor vendors or the electric utility industry. Architectural engineering firms also conduct some nuclear research, some of which is safety research, but the committee estimates the level of safety research by architectural engineering firms at less than $10 million.

Utilities sponsor research either by contracting for it or by performing it themselves. In general, only the larger utilities, like Tennessee Valley Authority, Duke Power Company, Pacific Gas and Electric Company, and Commonwealth Edison Company, have the human and financial resources to conduct safety research apart from the work they sponsor through their membership in the Electric Power Research Institute (EPRI). For example, TVA is conducting research on advanced reactor design concepts and acoustic emission monitoring of reactor vessel flaws; Duke has an in-house Artificial Intelligence Demonstration Project; Pacific Gas and Electric is beginning a four-year study entitled "Field Studies to Support Off-site Dose Calculations at Nuclear Power Plants"; and Commonwealth Edison is conducting research to assess the addition of hydrogen to reactor coolant as a potential means of arresting crack propagation in reactor coolant system piping. Several nuclear utilities, including the New York Power Authority and Northeast Utilities, have performed probabilistic risk assessments on their reactors; and some, such as Arizona Public Service Company, cofund Gas Cooled Reactors Associates, an organization sponsored primarily by the utilities and by DOE that conducts research on gas-cooled advanced reactors. Some of the smaller utilities do sponsor research independently of EPRI. For example, Portland General Electric is currently sponsoring a small program of thermal hydraulics research at Oregon State University; Yankee Atomic is involved in development work to explore design improvements and to improve calculational methods; and Baltimore Gas and Electric Company supports the Johns Hopkins NDE (Nondestructive Examination) Center.

In recent years the utility industry has also sponsored a number of ad hoc projects of a short-term nature directed, like the Owners Groups discussed below, at specific problems. This year, one of these—the Industry Degraded Core Rulemaking project (IDCOR)—will come to a close. The purpose of IDCOR was to develop a technical understanding of the issues related to severe accidents using the best available information, to develop an integrated methodology for assessing reactor severe accident behavior, and to serve as a unified industry point of contact with the NRC, which had undertaken a large-scale program of severe accident research after the accident at Three Mile Island. IDCOR led to the development of new mathematical models and analytical codes for assessing reactor behavior during severe accidents, and these were used to analyze four reference plants. IDCOR has nearly completed developing simplified techniques for use by utilities with nuclear power plants to enable them to screen for susceptibilities to severe accidents.

Aside from the vendors, the principal sponsor of nuclear safety research in the private sector is EPRI, headquartered in Palo Alto, California. EPRI was formed by the electric utility industry in 1972. Utility membership in EPRI is voluntary; financial support for EPRI research by a member utility is based on the amount of power it produces. Nuclear safety research is conducted by EPRI's Nuclear Power Division, which had expenditures in 1985 of about $65 million, which is about $4 million more than was budgeted for that year. Only about one-third of EPRI's 1985 expenditures, however, were for safety research. Although figures on expenditures for 1986 are not yet available, the committee is told that they are likely to be somewhat lower than in 1985.

Roughly 90 to 95 percent of EPRI's nuclear research is targeted at current light water reactors, and about half of the advanced reactor R&D budget ($5.4 million in 1985) is devoted to breeder and advanced gas reactors, with the remainder funding research on improved light water reactors. In sum, as in the case of DOE, most of the research undertaken by EPRI's Nuclear Power Division does not have safety as its primary emphasis; perhaps 30 to 35 percent of the work does, but the majority is aimed at

TABLE A.7 EPRI Nuclear Power Division Budgets, 1973-1985, in Current and Constant 1985 Dollars

	Current Dollars	Constant Dollars
1973	5.0	11.3
1974	4.2	8.7
1975	15.0	28.4
1976	29.5	53.0
1977	35.8	60.9
1978	48.6	76.9
1979	48.9	71.2
1980	53.5	71.4
1981	55.1	67.2
1982	57.6	66.3
1983	68.6	76.4
1984	60.7	64.0
1985	60.9[a]	60.9
TOTALS	543.4	716.6

[a] Planned spending (actual expenditures were somewhat higher after accounting for rollovers and reductions from commitments made in previous years.)

improving power plant economics (e.g., availability and reliability) which may yield safety improvements as a by-product.

Table A.7 shows figures for the EPRI Nuclear Power Division since its inception. In thirteen years the Nuclear Power Division has funded more than half a billion dollars of research. In current dollars the peak year was 1983, when nearly $70 million was expended. In constant dollars spending peaked in 1978. Both of these cases are anomalous. If one looks at the overall trend in constant dollars, spending went up until the late 1970s and has been decreasing since then.

Table A.8 shows actual expenditures by EPRI's Nuclear Power Division in 1985 both in terms of the type of research conducted and the sector of the contract research community that performed it.

Table A.9 shows the percentages of EPRI, DOE, and NRC prime contracts allocated among different sectors of the contract research community. The total value of this research (in mixed 1985 and 1986 dollars) is approximately $356 million; but it is

TABLE A.8 EPRI Nuclear Power Division 1985 Expenditures by Program and Contractor (thousands of dollars)

	U.S. government							
	National Laboratories	Other	Universities	Industry	Foreign	EPRI	Other	Totals
Risk assessment	80	0	315	6,312	285	542	-263	7,268
Source term	3,352	1,575	356	2,963	378	0	-1,353	7,273
Analytical methods and verification	506	5	65	3,165	8	0	11	3,757
Safety control and testing	209	475	375	4,557	125	0	14	5,753
Component reliability	53	72	508	8,598	71	443	119	9,865
LWR fuel and spent fuel storage	153	0	152	3,439	671	0	13	4,428
Corrosion control	230	0	515	4,476	880	0	-139	5,960
Plant availability	0	0	225	4,006	21	16	0	4,269
Life extension and constructibility	0	25	85	2,222	15	20	0	2,370
Low-level waste and coolant technology	3	0	424	3,213	559	13	0	4,212
Advanced nuclear generation	0	50	120	7,025	0	116	-25	7,286
Generic safety	75	0	0	1,737	0	32	0	1,844
Subtotals	4,661	2,202						
TOTALS	6,863		3,140	51,713	3,013	804	-1,245	64,285

NOTE: Rows may not add up due to rounding.

TABLE A.9 Patterns of DOE, EPRI, and NRC Support for Nuclear R&D (prime contracts in thousands of dollars)

	DOE[a]		EPRI[b]		NRC[c]	
U.S. government	117,822	(64.8%)	6,863	(10.5%)	94,038	(86.4%)
Universities	6,600	(3.6%)	3,140	(4.8%)	3,067	(2.8%)
Industry	57,322	(31.5%)	51,713	(78.9%)	11,396	(10.5%)
Foreign	0	--	3,013	(4.6%)	260	(0.2%)
Other	0	--	804	(1.2%)	125	(0.1%)
TOTALS	181,744	(100.0%)	65,533	(100.0%)	108,886	(100.0%)

[a] Primarily non-safety-related research, FY 1986.
[b] Primarily non-safety-related research, CY 1985.
[c] Primarily safety-related research, FY 1986.

important to reiterate that the greatest part of these funds was not earmarked for nuclear safety research.

One finds clear distinctions among the principal sponsors of nuclear R&D. In total dollars, DOE provides over half of all of the nuclear R&D sponsored by these three organizations ($182 million of a total of $356 million, or 51 percent). Dollar for dollar, DOE provides more support for nuclear research conducted by federal laboratories, by universities, and by the private sector than any other sponsor, public or private.

On a percentage basis, however, the picture is a little different. The NRC spends by far the largest share of its available research budget on work performed in federal laboratories. EPRI spends more, proportionately, than either of the others for research conducted either in the universities or in industry. The proportion that EPRI spends for research in industry is significantly more than either government agency, and the total dollar amount of this research is on a par with the amount that DOE provides to industry for civilian nuclear R&D. The NRC, on the other hand, provides the least support for nuclear research whether performed in the universities or in the private sector, and whether on a percentage or total dollar basis.

The utility industry sponsors and conducts research through several additional mechanisms. One of these is the so-called Owners Group. Research in several specific areas—for example, TABLE A.10 1985 Allocation of Owners Group Contracts (thousands of 1985 dollars)

	A	B	C	D	E	F	Totals
U.S. government	0	329	0	0	7	537	873
National laboratories	0	329	0	0	7	537	873
Other U.S. government	0	0	0	0	0	0	0
Universities	0	279	162	0	0	59	500
Industry	69	7,039	1,837	359	1,052	3,584	13,940
Foreign	0	1,148	0	734	0	0	1,882
Internal use	0	0	0	0	0	0	0
Other[a]	0	-145	-550	-350	0	-20	-1,065
TOTALS	69	8,876	1,450	743	1,059	4,158	16,130

A - Steam Generator Owners Group I
B - Steam Generator Owners Group II
C - Seismicity Owners Group
D - Nuclear Fuel Industry Research Owners Group
E - Hydrogen Control (BWR6/Mark III) Owners Group
F - Boiling Water Reactors Owners Group II

NOTE: Columns may not add up due to rounding.

[a] Unidentified contracts minus reductions from previous years commitments.

steam generator performance and stress corrosion in boiling water reactors—is managed by EPRI; but it is funded and has its agenda set by a utility Owners Group, which consists of a group of utilities in partnership with one or more reactor vendors, foreign utilities, or industrial firms, depending on the research area. Funding is arranged by the Owners Group rather than out of general EPRI funds. This approach is followed for several reasons. Often the benefits from the research apply to a limited number of utilities. Foreign utilities, which are not permitted to join EPRI, can provide funding and participate in research decisions more easily through Owners Group activities. And agreements regarding the scope of the research and the funding responsibility of vendors can be developed on a programmatic basis. In addition to the two areas identified above, EPRI manages Owners Group programs on hydrogen control, nuclear fuel, and seismic research. As Table A.10 indicates, these programs fund an additional $16 million of nuclear research.

The Institute of Nuclear Power Operations (INPO) in Atlanta disclaims conducting research, but it does collect and distribute operating data to the nuclear utility industry and conducts audits of power plant operations with the aim of defining and promoting standards of operational excellence. In particular, INPO manages the nuclear plant reliability data system (NPRDS), which consists of two data bases. One is a component failure reporting data base, and the other is an engineering data base. This information is not only valuable for member utilities to determine histories of particular types of equipment, but also serves as the data base necessary for finding accident precursors and for doing statistical treatments included in probabilistic risk analyses. INPO estimates that the annual cost of operating the NPRDS system is about $1.4 million. A major upgrade of the system, including over $1 million in new programming, is scheduled for FY 1987.

Appendix B

Planned FY 1986 Safety Research Program of the Nuclear Regulatory Commission

A. REACTOR ENGINEERING DECISION UNIT

1. TITLE: LOAD COMBINATIONS
CONTRACTOR: Lawrence Livermore National Laboratory

	FY 85	FY 86	FY 87
BUDGET:	115	225	0

OBJECTIVE:

General Design Criterion 4 has resulted in the installation of protective devices (e.g., pipe whip restraints and jet impingement barriers) to mitigate events which are now regarded as extremely unlikely for PWR reactor coolant loops. These protective devices impede inservice inspection and maintenance, reduce safety if improperly installed, and increase worker radiation exposures. It is now generally believed that the number of protective devices can be reduced because pipe degradation will be detected through leakage monitoring before breaking occurs. The objective of this program is to provide the licensing staff with the technical basis for applying the leak-before-break concept to reactor coolant loop piping.

2. TITLE: SEISMIC MARGINS STUDIES
CONTRACTOR: Lawrence Livermore National Lab

	FY 85	FY 86	FY 87
BUDGET	591	600	500

OBJECTIVE:

Nuclear power plants are designed to resist large earthquakes. However, as new seismological data are obtained throughout the U.S., the appropriateness of current plant design earthquake levels has been questioned. There is concern over the ability of current light water reactor plant designs to accommodate earthquakes larger than the design basis and to adequately protect the public health and safety. The objective of this program is to provide the licensing staff with a procedure to evaluate the seismic design margin of light-water-reactor plants with potentially increased design basis earthquakes. This will serve as the basis or regulatory decision on the acceptability of licensee submittals regarding the continued operation of their facilities.

3. SEISMIC RISK METHOD. TECH TRANSFER
CONTRACTOR: Lawrence Livermore National Lab

	FY 85	FY 86	FY 87
BUDGET	100	100	0

OBJECTIVE:

Nuclear power plants are designed to resist large earthquakes. However, as new seismological data are obtained throughout the U.S., the appropriateness of plant design earthquake levels have been questioned. There is concern over the ability of current light water reactor plant designs to accommodate earthquakes larger than the design basis and to adequately protect the public health and safety. The objective of this program is to transfer computer codes and data developed under the SSMRP to national laboratories and other entities engaged in seismic studies, with the intent that these facilities could assist the NRC staff in evaluating seismic design criteria. In addition, the seismic information developed as part of this research program will be used to help establish international technical exchange agreements from which NRC can obtain information from other countries.

4. TITLE: ASSESS & IMP OF SPECTRUM-BROADENING PROC USED IN PIPING DESIGN		FY 85	FY 86	FY 87
CONTRACTOR: Lawrence Livermore National Lab	BUDGET	50	75	0

OBJECTIVE:

NRC dynamic load design criteria have led to the placement of large numbers of snubbers and rigid supports on nuclear plant piping. The installation of too many restraints has potentially detrimental effects. Because of the stiffening they provide, the restraints which are installed to resist earthquake and other dynamic loads have increased the thermal forces on the piping systems during normal operating conditions. In addition, the snubber have proven to be unreliable devices that require extensive inservice inspection and maintenance, resulting in increased levels of worker radiation exposure. The objective of this program is to provide the NRC staff with the information necessary to evaluate licensee submittals to reduce the conservations associated with defining in-plant response spectra for seismic loads on piping systems, and thereby use fewer restraints.

5. TITLE: VALIDATION, PLANNING & COORD		FY 85	FY 86	FY 87
CONTRACTOR: Argonne National Lab	BUDGET	365	625	900

OBJECTIVE;

Nuclear power plants are designed to resist large earthquakes. However, as new data are obtained on earthquake activity throughout the U.S., plant design earthquake levels have increased. There is concern over the ability of current light water reactor plant designs to accommodate these larger earthquakes and to adequately protect the public health and safety. Thus, there is a high priority need to establish seismic design margins of these plants. The objective of this program is to provide, through domestic and international cooperative efforts, information and experimental data which can be used to validate and improve predictions of the behavior of nuclear power plants (including soil-structure interaction and the nonlinear behavior of buildings and piping system) subjected to earthquakes larger than design basis. The predictive methods to be validated are used both in probabilistic and deterministic calculations and in particular may be used as part of Seismic Probabilistic Risk Assessments (PRAs) for nuclear power plants.

		FY 85	FY 86	FY 87
6. TITLE: BENCHMARKING COMPUTER CODES FOR STRUC ENGR. CONTRACTOR: Brookhaven National Laboratory	BUDGET	300	200	200

OBJECTIVE:

Nuclear power plants are designed to resist large earthquakes. However, as new data are obtained on earthquake activity throughout the U.S., plant design earthquake levels have increased. There is concern over the ability of current light water reactor plant designs to accommodate these larger earthquakes and to adequately protect the public health and safety. The objective of this program is to establish problems with experimentally known solutions (benchmarks) for use by the licensing staff to validate major parts of licensee methods used to calculate the transmittance of earthquake loads through the soil to safety-related buildings, systems and components.

		FY 85	FY 86	FY 87
7. TITLE: SEISMIC COORD 7 SSMRP TECH TRANSFER CONTRACTOR: Brookhaven National Laboratory	BUDGET	234	100	1000

OBJECTIVE:

Nuclear power plants are designed to resist large earthquakes. However, as new data are obtained on earthquake activity throughout the U.S., plant design earthquake levels have increased. There is concern over the ability of current light water reactor plant designs to accommodate these larger earthquakes and to adequately protect the public health and safety. The objective of this program is to validate, through domestic and international cooperative efforts, those computer codes used to predict the nonlinear behavior of piping systems and buildings subjected to earthquakes larger than the design basis. These validated computer codes can then be used by the licensing staff as a basis for evaluating licensee submittals.

		FY 85	FY 86	FY 87
8. TITLE: COMP FRAGILITY DATA ACQUISITION & EVAL CONTRACTOR: Brookhaven National Laboratory	BUDGET	240	875	1000

OBJECTIVE:

Nuclear power plants are designed to resist large earthquakes. However, as new data are obtained on earthquake activity throughout the U.S., plant design earthquake levels have increased. There is concern over the ability of current light water reactor plant designs to accommodate these larger earthquakes and to adequately protect the public health and safety. Although large uncertainties exist in predicting the earthquake level at which critical components fail to perform their safety function (because qualification data cannot be extrapolated to accurately predict failure level), it is now believed components have greater resistance to earthquake loads than previously estimated. The objective of this program is to establish an experimental data base on component fragility through domestic and foreign cooperative efforts. This data base will provide the licensing staff with a basis for assessing the earthquake levels at which individual components and generic classes of components fail to perform their safety functions.

9. **TITLE: REL ANALYSIS OF NON-LINEAR BEHAVIOR OF CONCRETE STRUCTURES**
CONTRACTOR: Brookhaven National Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	200	200

OBJECTIVE:
Develop a reliability analysis method and a stochastic nonlinear analysis method for concrete containments and shear walls subjected to multiple static and dynamic loads that produce nonlinear behavior. Extend RAS code to include nonlinear behavior. Define when appropriate to use this nonlinear method or the simplified (linear SSMRP) method. Verify the approximate nonlinear limit states from A-3002.

10. **TITLE: DAMPING STUDIES**
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	230	200	0

OBJECTIVE:
NRC dynamic load design criteria have led to the placement of large numbers of snubbers and rigid supports on nuclear plant piping. The installation of too many restraints has potentially detrimental effects. Because of the stiffening they provide, the restraints which are installed to resist earthquake and other dynamic loads have increased the thermal forces on the piping systems during normal operating conditions. In addition, the snubbers have proven to be unreliable devices that require extensive inservice inspection and maintenance, resulting in increased levels of worker radiation exposure. The objective of this program is to provide the NRC staff with information with which to evaluate licensee submittals to increase the level of damping for plant piping systems and thereby reduce the number of snubbers without reducing the level of plant safety.

11. TITLE: SEISMIC CATEGORY 1 STRUCTURES PGM
CONTRACTOR: Los Alamos National Laboratory

	FY 85	FY 86	FY 87
BUDGET	820	1200	1500

OBJECTIVE:

Nuclear power plants are designed to resist large earthquakes. However, as new data are obtained on earthquake activity throughout the U.S., plant design earthquake levels have increased. There is concern over the ability of current light water reactor plant designs to accommodate these larger earthquakes and to adequately protect the public health and safety. The objective of this program is to validate existing methods and, as necessary, to develop new methods to reduce uncertainties that exist in the methods used by the NRC staff to predict the transfer of the increased earthquake loads used by plant buildings to safety systems and components needed to operate and shutdown the plant, and to provide a basis for regulatory decisions regarding continued operation of these facilities.

12. TITLE: PIPE-TO-PIPE IMPACT
CONTRACTOR: Pacific Northwest

	FY 85	FY 86	FY 87
BUDGET	25	25	0

OBJECTIVE:

Nuclear power plants are designed for many types of postulated accidents, including pipe breaks. Certain types of pipe breaks may cause the broken pipe to whip freely and impact nearby components and other piping. It is important that such impacts not cause safety equipment to malfunction and prevent plant shutdown. The objective of this program is to determine whether existing licensing criteria on pipe-to-pipe impact are acceptable, and to develop new criteria where necessary.

13. TITLE: SEISMIC FRAGILITY DEMONSTRATION PIPING TEST
CONTRACTOR: Energy Tech Engr. Corp.

	FY 85	FY 86	FY 87
BUDGET	92	100	0

OBJECTIVE:

NRC dynamic load design criteria have lead to the placement of large numbers of snubbers and rigid supports on nuclear plant piping. The installation of too many restraints has potentially detrimental effects. Because of the stiffening they provide, the restraints which are installed to resist earthquake and other dynamic loads have increased the thermal forces on the piping systems during normal operating conditions. In addition, the snubbers have proven to be unreliable devices that require extensive inservice inspection and maintenance, resulting in increased levels of worker radiation exposure. The primary objective of this program is to provide the NRC staff with information to evaluate whether the ASME Code failure mode criterion for dynamic loads is overly conservative. Modifications to the Code criterion would permit the use of fewer restraints without reducing the overall level of plant safety. A secondary objective of this program is to validate current assumptions on piping fragility (i.e., failure levels) that influence the results of seismic probabilistic risk assessment studies.

14. TITLE: PIPE CAPACITY/FAILURE MODES CONTRACTOR: Anco		FY 85	FY 86	FY 87
	BUDGET	100	700	700

OBJECTIVE:
NRC dynamic load design criteria have led to the placement of large numbers of snubbers and rigid supports on nuclear plant piping. The installation of too many restraints has potentially detrimental effects. Because of the stiffening they provide, the restraints which are installed to resist earthquake and other dynamic loads have increased the thermal forces on the piping systems during normal operating conditions. In addition, the snubbers have proven to be unreliable devices that require extensive inservice inspection and maintenance, resulting in increased levels of workers radiation exposure. The objectives of this program are to clearly and systematically demonstrate the failure modes of piping due to dynamic invertial loads, and to provide the basis for changing ASME code rules regarding seismic piping stress criteria.

15. TITLE: DESIGN CRITERIA FOR SHIPPING CONTAINERS CONTRACTOR: Lawrence Livermore National Lab		FY 85	FY 86	FY 87
	BUDGET	250	300	300

OBJECTIVE:
Shipping containers are used to store and transport spent radioactive fuel. There is concern over the ability of these containers to properly protect the public health and safety during postulated storage and transportation conditions. The objective of this program is to develop licensing criteria for the design and fabrication of spent fuel shipping containers, and to develop simplified thermal stress analysis procedures for use by the licensing staff in evaluating similar analyses by licensees.

16. TITLE: MECHANICAL EQ QUAL PROGRAM CONTRACTOR: Idaho National Engineering Laboratory		FY 85	FY 86	FY 87
	BUDGET	1186	2000	1800

OBJECTIVE:
The NRC requires that nuclear power plant equipment important to safety be qualified to assure operability during design basis accident conditions. Because qualification procedures are in many cases inadequately defined there are many areas where the procedures are inconsistent or incorrect. These areas include the proper mounting of equipment to be qualified; the proper definition of qualification loads; and the generic application of qualification test results. The objective of this program is to provide the licensing staff with the technical basis for evaluating equipment operability testing and to provide the technical basis for developing the criteria and methodologies to improve national standards and regulatory documents used to qualify specific mechanical equipment.

17. TITLE: ASME XI SUPPORT - TECHNICAL ASSISTANCE - RES
CONTRACTOR: Idaho National Engineering Lab

	FY 85	FY 86	FY 87
BUDGET	60	200	300

OBJECTIVE:

Assist the NRC staff in a thorough evaluation of proposed revisions and/or additions to the ASME Boiler and Pressure Vessel Code (ASME Code) rules which are used to detect nuclear power plant component degradation (including that of primary system piping) as they age in operating reactors, so that corrective action can be taken before safety is compromised. These rules, which are contained in Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components" of the ASME Code, are incorporated by reference, as appropriate, into the NRC regulations following the NRC staff evaluation of each new Section XI edition and addenda.

18. TITLE: ASME SECTION III
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	104	150	200

OBJECTIVE:

Assist the NRC staff in a thorough evaluation of proposed revision and/or additions to the ASME Boiler and Pressure Vessel Code (ASME Code), which provides rules for the design and construction of nuclear power plant components, to ensure that the quality of new components is adequate to protect the public health and safety. These rules, which are contained in Section III, "Rules for Construction of Nuclear Power Plant Components" of the ASME Code, are incorporated by reference, as appropriate, into the NRC regulations following the NRC staff evaluation of each new Section III edition and addenda.

19. TITLE: VALVE PERFORMANCE TESTING
CONTRACTOR: Energy Tech Engineering Corp.

	FY 85	FY 86	FY 87
BUDGET	370	200	200

OBJECTIVE:

Primary system isolation valves are used to separate and protect low pressure reactor systems from the high pressure of the primary system. The integrity of these isolation valves is presently verified by periodic inservice leak testing. The ability of these leak tests to adequately detect valve degradation is uncertain. Experiments are needed to reduce this uncertainty by developing a correlation between inservice leak tests and valve degradation. The objective of this program is to validate and improve existing technical specification (license condition) allowable leak rates and ASME Code (Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components") methodology for inservice testing of primary system isolation valves, to assure these valves crucial to safety will operate when called upon; and to evaluate advanced techniques for detecting valve degradation.

20. TITLE: EXPERIMENTS ON CONTAINMENT MODELS
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	2060	2000	2400

OBJECTIVE:

Severe accidents exceeding the original design basis that lead to core melt have been postulated. The containment building provides the last barrier to the release of radioactivity resulting from such an accident. There are large uncertainties in predicting the leak integrity of containment buildings under severe accident pressures and temperatures. The objective of this program is to implement tests on scale containment models to support development and validation of methods for assessing the capabilities of containment buildings under conditions exceeding their design basis to permit licensing staff evaluation of licensee estimates of containment performance and to support Commission policy on severe accidents.

21. TITLE: CONTAINMENT PENETRATIONS
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	900	900	600

OBJECTIVE:

Severe accidents exceeding the original design basis that lead to core melt have been postulated. The containment building provides the last barrier to the release of radioactivity resulting from such an accident. There are large uncertainties in predicting the leak integrity of containment buildings under severe accident pressures and temperatures. The objective of this program is to develop an experimental data base for assessing the leak integrity of containment penetrations under severe accident conditions and for validating existing methods used to assess these penetrations, in order to provide a basis for regulatory decisions regarding continued operation of existing facilities, and for identifying containment penetration features, which if improved, would significantly increase containment capacity.

22. TITLE: CONT INTEGRITY UNDER EXTREME LOAD
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	740	600	700

OBJECTIVE:

Severe accidents exceeding the original design basis that lead to core melt have been postulated. The containment building provides the last barrier to the release of radioactivity resulting from such an accident. There are large uncertanties in predicting the leak integrity of containment buildings under severe accident pressures and temperatures. The objective of this program is to provide a basis for the reliable estimation of containment performance during severe accidents.

23. TITLE: FISSION PRODUCT CONTROL ESF EFFECTIVENESS
CONTRACTOR: Pacific Northwest Labs

	FY 85	FY 86	FY 87
BUDGET	400	195	600

OBJECTIVE:

In evaluating potential releases of radioactivity from containment atmospheres to the environment as a result of severe light water reactor accidents, the effectiveness of certain Engineered Safety Features for removal of radioactive particulates is an important factor. This project will develop and validate codes and models to estimate particulate removal effectiveness of ice condensers and suppression pools.

24. TITLE: ICEDF CODE VERIF/VALID TESTS
CONTRACTOR: Pacific Northwest Labs

	FY 85	FY 86	FY 87
BUDGET	179	450	0

OBJECTIVE:

In evaluating potential releases of radioactivity from containment atmospheres to the environment as a result of severe light water reactor accidents, the effectiveness of certain Engineered Safety Features for removal of radioactive particulates is an important factor. This project will support experimental studies to be used in validation of a developed model and code for ice condenser effectiveness.

25. TITLE: ADDITIONAL REQUIREMENTS FOR MATERIALS
CONTRACTOR: Oak Ridge National Lab

	FY 85	FY 86	FY 87
BUDGET	75	150	200

OBJECTIVE:

Provide technical expertise and assistance to Research in the review of national codes and standards that may be referenced in NRC regulations or guides related to nuclear reactor components. Provide comments, proposed modifications and reviews as appropriate in the areas of design, materials, fabrication and inspection. When necessary, specific information (or data) will be developed and/or analyzed to support recommendations related to proposed regulations, guides, or referenced codes and standards.

26. TITLE: HEAVY SECTION STEEL TECH PROG
CONTRACTOR: Oak Ridge National Lab

	FY 85	FY 86	FY 87
BUDGET	5520	5200	5100

OBJECTIVE:

To provide a thorough, quantitative assessment of heavy-section reactor vessel fracture characteristics including a realistic evaluation of fracture potential and development of fracture prevention criteria, flaw growth mechanisms, crack propagation and crack arrest, including the effects of irradiation are considered. The development and evaluation of materials characterization methods, fracture mechanics analysis methods, the development of material data bases, and the validation of structural integrity analytical methods using thick-section structural tests are major activities in this program.

27. TITLE: PRESSURE VESSEL SIMULATION
CONTRACTOR: Oak Ridge National Lab

	FY 85	FY 86	FY 87
BUDGET	280	360	100

OBJECTIVES:

Validate in well-defined reproducible benchmark experiments, methodologies and data bases which are used to predict radiation damage in reactor pressure vessels. Considerable attention is given to the quality of data generated. A key element in this program is the need to set and achieve realistic uncertainties for neutron dosimetry and to ensure that these uncertainties are fairly propagated in the assessment of irradiated material performance. Rigorous variables are characterized and quantified in terms of their mean values and their associated uncertanties.

28. TITLE: RESIDENT ENGINEER - FRG
CONTRACTOR: Oak Ridge National Lab

	FY 85	FY 86	FY 87
BUDGET	120	130	130

OBJECTIVES:

Act as a resident engineer in Stuttgart, Germany, for the Division of Engineering Technology, Materials Engineering Branch, for liason to the materials, structural and safety programs underway at MPA and elsewhere. To provide information on European regulatory activities for comparision to or adoption into NRC regulations.

29. TITLE: SURVEILLANCE DOSIMETRY
CONTRACTOR: Hanford Engr Dev Lab

	FY 85	FY 86	FY 87
BUDGET	450	660	420

OBJECTIVE:

Preparation of updated and improved dosimetry, damage correlation, and the associated reactor analysis ASTM standards for LWR pressure vessel (PV) irradiation surveillance programs to assure conformance with 10CFR Part 50, Appendix G requirements. Perform supporting "Benchmark Fields," reactor "Test Regions," and operate power reactor "Surveillance Positions" validation and calibration testing of the recommended ASTM procedures, measurements, and analysis techniques.

		FY 85	FY 86	FY 87
30. TITLE: DOSIMETRY MEAS DATA BASE CONTRACTOR: National Bureau of Standards	BUDGET	210	200	100

OBJECTIVES:

Provide calibration of LWR-PV related surveillance dosimetry traceable to NBS standard neutron fields including distribution of neutron fluence standards. Such dosimetry is needed to accurately assess radiation damage in reactor pressure vessels and to assure conformance with 10CFR Part 50, Appendix G. Maintain a compendium of reference data for LWR-PV related benchmark neutron fields. Participate in the preparation of ASTM standards for routine LWR-PV dosimetry and in establishing consensus methods of data interpretation. Provide experimental assistance for LWR-PV dosimetry benchmark measurement programs.

		FY 85	FY 86	FY 87
31. TITLE: ELASTIC PLASTIC FRACTURE MECHANICS EVALUATION OF LWR ALLOYS CONTRACTOR: Naval Ship R&D Center	BUDGET	185	300	300

OBJECTIVE:

Through small and moderate scale experiments determine the critical parameters affecting ductile fracture toughness of nuclear grade steels and weldments, evaluate new test methods for possible standardization, and verify the applicability of new data analysis methods to existing specimen types.

		FY 85	FY 86	FY 87
32. TITLE: STRUCTURAL INTEGRITY OF H20 REACTOR BOUNDRY COMP II CONTRACTOR: Naval Ship R&D Center CONTRACTOR: Materials Engr. Assoc., Inc.	BUDGET	1800	2150	2100

OBJECTIVES:

To provide to the NRC analytical and experimental methods and data that are necessary for compliance with 10CFR50 Appendix A, GDC-14, 30 and 31, to ensure the structural safety and reliability of pressure boundary components in light water reactor components of U.S. commercial nuclear power systems. Specific objectives are:

a) Development of criteria for establishing elastic plastic fracture toughness.
b) An experimentally validated mechanism model for irradiation damage effect of reactor pressure vessel steels.
c) Modification of Code fatigue curves to recognize environmental effects.
d) An experimentally validated mechanism model for corrosion assisted fatigue crack growth.
e) A comprehensive computerized fracture mechanics data base for all steels and weldments in U.S. nuclear commercial power plant piping.

33. TITLE: GUNDREMMINGEN
CONTRACTOR: Noell, GG

	FY 85	FY 86	FY 87
BUDGET	0	100	0

OBJECTIVE:

Evaluation of irradiated pressure vessel material removed from a decommissioned reactor to determine effect of long-time irradiation at service temperature and low flux rate, for comparison to regulatory trends for rate of irradiation versus fluence from irradiations at a faster rate, to assure compliance with 10CFR50 Appendix A, GDC 14, 30 and 31. To measure fracture toughness values through the vessel thickness to validate the regulatory position on fluence and embrittlement gradients, to determine annealing recovery from in-situ irradiated vessel steel, and through parallel irradiation in test reactors, to measure the dose rate effect.

34. TITLE: HYDROGEN CONTROL
CONTRACTOR: Sandia National Lab

	FY 85	FY 86	FY 87
BUDGET	780	400	0

OBJECTIVE:

An igniter system is employed in a reactor containment to control the combustion of hydrogen that may result from certain possible accidents. Data are needed to reduce the uncertainties associated with the capability of an igniter system to perform its function, i.e., controlled burning of hydrogen without detonation, in the presence of water sprays provided to reduce the temperature of the containment atmosphere. Too much water on the igniter element would prevent the hydrogen-air mixture from reaching its ignition temperature. This project will provide the NRC licensing staff the information to evaluate the igniter systems and operational schemes proposed by reactor licensees.

35. TITLE: ENVIRONMENTALLY ASSISTED CRACKING IN LWR PIPING SYSTEMS
CONTRACTOR: Argonne National Laboratory

	FY 85	FY 86	FY 87
BUDGET	1715	1020	1000

OBJECTIVE:

To determine if the "fixes" proposed by industry for mitigation of intergranular stress corrosion cracks including induction heating stress improvement, hydrogen water chemistry, repair by weld clad overlay, or replacement material 316 NG (nuclear grade) will actually perform the crack mitigation and provide assurance of crack-free future service, to provide assurance that repaired cracks will not continue to grow and thus threaten catastrophic failure of the pipe system especially when it is known that the weld clad overlay precludes effective ultrasonic inspection to monitor any further growth.

36. TITLE: CAST STAINLESS STEEL
CONTRACTOR: Argonne National Lab

BUDGET	FY 85	FY 86	FY 87
	75	300	300

OBJECTIVE:

To evaluate if the loss in toughness suffered by cast stainless steel during normal operating service, is sufficient to render the steel so brittle that it will not stand up to operating or accident loads, and thus could fracture, leading to a loss of coolant accident, possible meltdown and exposure of the public to radiation. This program will measure the fracture toughness of such aged steels to determine whether the code requirements and NRC regulations are adequate for Leak Before Break and for the safety of the public against failure of the reactor primary system.

37. TITLE: AGING STUDIES ON MATERIALS FROM THE SHIPPINGPORT REACTOR
CONTRACTOR: Argonne National Laboratory

BUDGET	FY 85	FY 86	FY 87
	10	750	1250

OBJECTIVE:

To measure the properties of materials comprising the pressure vessel, thermal shield, piping, pumps and valves of the Shippingport reactor plant to determine how much change there has been due to service, and to help validate models of aging degradation due to time, temperature, pressure and radiation in reactor service.

38. TITLE: STRESS CORROSION CRACKING OF PWR STEAM GENERATOR TUBING
CONTRACTOR: Brookhaven National Laboratory

BUDGET	FY 85	FY 86	FY 87
	30	30	0

OBJECTIVE:

Develop data and models to be used by the regulatory staff to predict the stress corrosion cracking (SCC) service life if Inconel 600 steam generator tubing under normal and upset conditions and establish criteria for safe operation of such steam generators. Factors related to service and material conditions which influence SCC such as temperature, stress, strain and strain rate, metallurgical structure and processing and ingredients of the primary and secondary coolant are included as variables in the testing program and appropriate results and factors incorporated in the predictive models for SCC service life.

39. TITLE: STEAM GENERATOR INTEGRITY-GROUP PROJECT
CONTRACTOR: Pacific Northwest Laboratory

BUDGET	FY 85	FY 86	FY 87
	1250	1350	1250

OBJECTIVE:

To reduce the uncertainty of possible multiple and massive failures of steam generator tubing that have become dented, cracked or dangerously thinned down by wastage or intergranular attack during service in light water reactor steam generators, and to fully characterize the massive breaking up of structural and supporting components of the generators, the broken parts of which can hammer at the tubing to cause additional breaks, all of which results in loss of coolant accidents which could lead to core meltdown and serious exposure of the public to radiation. To improve the reliability of the non-destructive examination procedures which are the only means available for early warning of imminent tube failure which could lead to the loss of coolant and potential exposure of the public to radiation. Because of broad international concern about these problems this is an international program whose participants (France, Italy, Japan, EPRI) are contributing funds.

40. TITLE: WELDED & WELD-REPAIRED STAINLESS STEEL
CONTRACTOR: Pacific Northwest Laboratory

	FY 85	FY 86	FY 87
BUDGET	335	350	500

OBJECTIVE:

To evaluate whether or not the welding or repair welding of a pipe will cause sensitization that will likely develop into a stress corrosion crack during service which could break under an accident loading thus leading to a loss of coolant, possible core meltdown and significant exposure of the public to radiation. This program will develop a model for prediction of the degree of sensitization and the susceptibility to intergranular stress corrosion cracking of welded and repair welded stainless steel piping in LWR service so that licensing reviewers and IE and regional inspectors can perform independent evaluations of weld and weld repair procedures by applicant.

41. TITLE: DEGRADED PIPING PHASE II
CONTRACTOR: Battelle Columbus Lab

	FY 85	FY 86	FY 87
BUDGET	1000	1250	1200

OBJECTIVE:

Experimentally determine the capacity of cracked ductile piping to withstand normal, transient and accident loading conditions to assure compliance with 10CFR50 Appendix A, GDC 14, 30 and 31. Develop and validate ducticle fracture mechanics analyses for predicting the loading capacity and failure mode of cracked pipes.

42. TITLE: INTL PIPING INTEG RESEARCH GP (IPIRG)
CONTRACTOR: Battelle Columbus Labs

	FY 85	FY 86	FY 87
BUDGET	0	650	500

OBJECTIVE:

To develop, improve and verify engineering methods for assessing the integrity of nuclear power plant piping containing defects, and to develop the technology to justify plant life extension and simplifications in nuclear plant piping design criteria.

43. TITLE: LEAK DETECTION
CONTRACTOR: Argonne National Lab

	FY 85	FY 86	FY 87
BUDGET	450	550	600

OBJECTIVE:

To validate that acoustic emission technology can be used for leak detection to provide additional confidence that the Leak Before Break regulatory principle can be maintained.

44. TITLE: IMP EDDY CURRENT INSERVICE INSP FOR STEAM GEN TUBING
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	100	150	200

OBJECTIVE:

To verify and upgrade inspections required by ASME code, and assure validity of tube plugging and inspection plan criteria set forth in Reg Guides 1.83 and 1.121. To demonstrate significantly improved capability for detection and sizing of all kinds of flaws and degradation in steam generator tubing, so that the reliability of such inspections will be greatly increased (and the uncertainty about the reliability of in-service inspection results will be greatly reduced) thus greatly lessening the possibility of unexpected and massive tube failures resulting in loss of coolant and exposure of the public to radiation. The unrealiability of present methods, and the need for such improved methods, is demonstrated by the round robin inspection trials of the Steam Generator Group Project using the retired Surry steam generator.

45. TITLE: ACOUSTIC EMMISSION MATERIAL STUDY
CONTRACTOR: Pacific Northwest Lab

	FY 85	FY 86	FY 87
BUDGET	600	200	200

OBJECTIVE:

To validate that acoustic emmission technology can be used as a continuous monitor to provide assurance that cracks, have neither initialized nor are growing and thus that the pressure boundary is not endangered and remains in compliance with 10CFR50, Appendix A, General Design Criteria 30, 31 and 32. The technology is a key method of assuring Leak Before Break in piping systems and thus preclude violation of that new regulatory basis.

46. TITLE: INTEGRATION OF NDE RELIABILITY AND FRACTURE MECHANICS BUDGET CONTRACTOR: Pacific Northwest Laboratories	FY 85	FY 86	FY 87
	1200	1200	1200

OBJECTIVE:

To establish the effectiveness and adequacy of inservice inspections to reliably find and accurately size flaws in reactor pressure vessels and piping systems using current and advanced nondestructive examination techniques. To determine the impact of inservice inspection reliability on system integrity and to reduce the uncertainty in safety evaluations through quantitative knowledge of the inspection reliability. To recommend ASME Boiler and Pressure vessel Code and NRC regulatory changes to inspection criteria (sampling plan, frequency of inspections) based on material properties, service conditions and inspection uncertainties and develop the requirements for demonstration of qualification inspection personnel, procedures and equipment to assure that flaws can be reliably found and evaluated as plants age to avoid unexpected failures.

47. TITLE: REAL TIME SAFT-UT CONTRACTOR: Pacific Northwest Labs BUDGET	FY 85	FY 86	FY 87
	600	300	300

OBJECTIVE:

To reduce the uncertainty in safety evaluations by improving the detection reliability and sizing accuracy of flaws in light water reactor nuclear components, to assure that component failures and corresponding loss of coolant accidents cannot occur because a severe flaw was missed during inspection or because a large flaw was allowed to remain in service since it was improperly thought to be of much smaller size. This program is completing field validation of a new untrasonic test inspection method, SAF-UT, that will provide this greatly enhanced detection and sizing capability that can be used by the NRR staff for third party checks on questionable inspection results from the field. To incorporate the method into the ASME Boiler and Pressure Vessel Code and or NRC Regulatory requirements to provide improved results from commercial inservice inspection of nuclear reactor components.

48. TITLE: POSTMORTEM EXAMS OF EQUIP - PLANT AGING BUDGET CONTRACTOR: Brookhaven National Laboratory	FY 85	FY 86	FY 87
	575	650	1250

OBJECTIVE:

To identify and characterize aging and sevice wear effects associated with selected safety system equipment. Also, determine how aging and service wear affects the capability of selected equipment to perform its function during or after seismic events and what methods might be practical and cost effective in detecting significant aging and service wear deterioration that may compromise its seismic performance.

49. TITLE: SURVEY OF AGED POWER PLANT PLANT FACILITIES
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	351	1050	1500

OBJECTIVE:

The major objectives of this research element are to identify, at plant level, LWR systems and components which might develop aging concerns and impact safety as plant operations continue; to perform a structured aging assessment study on a selected fluid-mechanical and electrical system and to develop a plan for residual life evaluation of vital safety system mechanical components.

50. TITLE: DECONTAMINATION METHODS - EPP AND SAFETY
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	100	0	400

OBJECTIVE:

The increased utilization of in situ decontamination of primary coolant systems and associated equipment has raised questions within the Nuclear Regulatory Commission as to the effectiveness of the decontaminations in reducing occupational exposure. This program is to obtain information, by collecting actual operating experience, on decontamination methods in reducing occupational exposures, waste forms generated, and potential problem areas.

51. TITLE: DEGRADATION MONITORING NPP SAFETY EQUIPMENT
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	905	1300	1500

OBJECTIVE:

Evaluate and identify practical and cost effective methods for detecting, monitoring and assessing the severity of time dependent degradation (aging) of electrical and mechanical components and structures in nuclear power plants. Emphasis will be on methods for detection of the onset of incipient defects prior to failures and on assessment of periodic maintenance and surveillance schedules for vital components in plant safety systems.

52. TITLE: LWR AGING STUDIES; SHIPPIN PWR AGING EVALUATION
CONTRACTOR: Pacific Northwest Laboratory

	FY 85	FY 86	FY 87
BUDGET	475	700	1000

OBJECTIVE:

- A. Evaluate the relevancy of components and materials at Shippingport - PWR as a source of plant aging information, perform in-situ assessments of aged components and obtain equipment for post service examinations and tests.
- B. Evaluate and assess the system performance of hydraulic and mechanical snubbers. Establish failure mechanisms and causes and provide recommendations for practical and cost effective application, operation, and maintenance.
- C. Make recommendations and generate guidelines for inspection, surveillance conditions monitoring methods and maintenance for room coolers and emergency diesel generators associated with plant safety systems.

53. TITLE: FACILITIES UNDERGOING DECOMMISSIONING
CONTRACTOR: United Nuclear Corp.

	FY 85	FY 86	FY 87
BUDGET	475	700	1000

OBJECTIVE:

Provide the NRC licensing staff data which will allow an assessment of radiation exposure during decommissioning and the implementation of ALARA techniques. Provide information to determine the proper amount of funds which must be available to ensure timely and safe decommissioning operations. This information is being used by NRR for evaluation of reactor decommissioning plans and will be used by RES in the development of the final decommissioning rule and in the proposed residual contamination rule.

54. TITLE: FIRE PROTECTION RESEARCH
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	800	650	500

OBJECTIVE:

Probabilistic risk assessments (PRA) have indicated that fires may contribute a significant fraction of the risk from nuclear plants, but there are large uncertainties in estimating the risk because of lack of data quantifying heat and corrosive materials generated by fires, their transport through the plant, the effects on safety equipment, and the relative effectiveness of fire protection measures to suppress fires and prevent damage to safety equipment. The objective for FIN A-1010 is therefore to develop test data for use in (a) evaluation of residual risk from fires in nuclear power plants in order to determine whether the licensing requirements for fire protection need to be modified, and (b) assessment of proposals by licensees for implementation of current regulations.

55. TITLE: QUAL TESTING EVALUATION
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	1600	1355	1600

OBJECTIVE:

Evaluate the procedures and methods used to qualify safety related electrical equipment to assure that they survive and function during and following an accident taking into account the effects of aging prior to the accident.

56. TITLE: EQUIPMENT SURVIVABILITY
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	70	300	200

OBJECTIVE:

1. Analyses and equipment thermal response tests to provide data for licensing decision on equipment survival in large dry PWR containment.
2. Develop criteria for assessing Hydrogen Control Owners Group (HCOG) experiments on equipment survival in a BWR MK III containment with standing flames.

57. TITLE: ELECTRIC PENETRATION ASSEMBLIES
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	107	250	100

OBJECTIVE:

1. Evaluate the containment integrity, leakage and potential failure mechanisms with electrical penetration assemblies (EPA) used in the three principal reactor containments (PWR, MI I BWR and MK III BWR) when exposed to a severe accident environment.
2. Determine the electric functional behavior of the EPAs under these same accident conditions.

58. TITLE: TESTING EQUIPMENT - SEVERE ACCIDENT SEQUENCES
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	50	150	400

OBJECTIVE:

Confirm the adequacy of data obtained from plant instrumentation and the availability of electrical equipment under severe accident states which provide the basis for operational and emergency preparedness actions; provide more accurate data for deterministic and probabilistic calculations as they pertain to severe accident states.

59. TITLE: FIRE PROTECTION RESEARCH
CONTRACTOR: Brookhaven National Laboratory

	FY 85	FY 86	FY 87
BUDGET	200	350	200

OBJECTIVE:

Probabilistic risk assessments (PRA) have indicated that fires may contribute a significant fraction of the risk from nuclear plants, but there are large uncertainties in estimating the risk because of lack of data quantifying heat and corrosive materials generated by fires, their transport through the plant, the effects on safety equipment, and the relative effectiveness of fire protection measures to suppress fires and prevent damage to safety equipment. The objective for FIN A-3252 at Brookhaven National Laboratory is to develop a computational capability for use in (a) evaluation of residual risk from fires in nuclear power plants, and (b) assessment of proposals by licensees for implementation of current regulations.

60. TITLE: OPER AVAIL OF INSTRUMENTS FOR SEVERE ACCIDENTS
CONTRACTOR: Idaho National Engineering Lab

	FY 85	FY 86	FY 87
BUDGET	300	150	300

OBJECTIVE:

Confirm the adequacy of data obtained from plant instrumentation and the availability of electrical equipment under severe accident states which provide the basis for operational and emergency preparedness actions; provide more accurate data for deterministic and probabilistic calculations as they pertain to severe accident states.

B. THERMAL HYDRAULICS DECISION UNIT

61. TITLE: MIST INSTRUMENT FACILITY SUPT
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	465	300	300

OBJECTIVE:

Provide advanced instrumentation, analysis and consulting support for MIST test program, which has as its objective to provide experimental data unique to the NRC safety analysis code verification.

62. TITLE: MIST & OTIS ANALYSIS
CONTRACTOR: Los Alamos National Laboratory

	FY 85	FY 86	FY 87
BUDGET	405	400	400

OBJECTIVE:

To provide code analysis and consulting support for MIST program, which has as its objective to provide experimental data unique to the B&W reactor system geometry for NRC safety analysis code verification.

63. TITLE: MIST/OTIS LOOP FACILITY CONTRACTOR: Babcock & Wilcox		FY 85	FY 86	FY 87
	BUDGET	4500	2425	3500

OBJECTIVE:

To provide the only full pressure integral system experimental data unique to the B&W system design for addressing safety and licensing issues and code assessment requirements for transients involving SBLOCA (small break loss-of-coollant accidents), reestablishment of natural circulation and steam generator tube rupture (SGTR). This will provide data needed by NRR and B&W Owners to resolve uncertainties raised by the Three-Mile Island Accident in 1979 with respect to the ability of emergency cooling or different operating procedures to prevent fuel damage and radionuclide release.

64. TITLE: 3D INSTRU SUPPORT CONTRACTOR: Idaho National Engineering Laboratory		FY 85	FY 86	FY 87
	BUDGET	750	500	450

OBJECTIVE:

To provide technical support and instrumentation services for several facilities of the 2D/3D program in Germany and Japan.

65. TITLE: TRAC APPLICATIONS TO 2D/3D CONTRACTOR: Los Alamos National Laboratory		FY 85	FY 86	FY 87
	BUDGET	2621	1900	2350

OBJECTIVE:

To calculate with TRAC multidimensional processes during the refill and reflood stages of a PWR LOCA in order to plan and coordinate multidimensional experiments providing data to assess NRC best-estimate licensing codes under large break (LOCA) conditions. To perform post-test predictions and analyses for the refill/reflood tests being performed in Japan and Germany. To resolve uncertainties in the three dimensional (cross) flows of steam and liquid along with fall back of liquid from the upper plenum into the reactor core. The above objectives support the ultimate objective of developing more realistic thermal hydraulic codes to predict plant performance under accident conditions.

66. TITLE: ADV INSTRUMENTATION FOR PWR REFLOOD STUDIES CONTRACTOR: Oak Ridge National Laboratory		FY 85	FY 86	FY 87
	BUDGET	570	300	250

OBJECTIVE:

To provide two-phase flow instrumentation for large scale reflood studies.

67. TITLE: LOCA/ECCS SUPPORT STUDIES
CONTRACTOR: WPR Associates

	FY 85	FY 86	FY 87
BUDGET	695	350	350

OBJECTIVE:

1. To provide technical support for revising 10 CFR 50 Appendix K rules.
2. To provide technical support for analyzing data for improved understanding of the loss-of-coolant accident (LOCA) phenomena and computer code TRAC assessment.

68. TITLE: ROSE 4 TECH SUPPORT
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	680	550	500

OBJECTIVE:

To obtain thermal-hydraulic experimental data from a facility of sufficiently large scale to verify existing small scale data. Scaling uncertainties become important in some accidents that are affected by the higher surface to volume ration of small test facilities. For instance, ROSA-IV will help resolve uncertanties in an accident discovered in the Semiscale facility in which larger than expected water level depression in the core was experienced with accompanying fuel heat up as a result of liquid hold-up in other parts of the primary system.

69. TITLE: TECHNICAL SUPPORT TO JAERI
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	220	0	400

OBJECTIVE:

To obtain data from large scale integral thermal hydraulic test facilities. The data are to be used to evaluate safety analysis codes which are being used by the NRC licensing staff to audit licensees. The data are to be obtained as economically as possible from foreign facilities through exchange of instrumentation and computer codes. Scaling uncertainties become important in some accidents that are affected by the higher surface to volume ratio of small facilities. Specifically, the data obtained is to help resolve uncertainties in an accident discovered in the Semiscale facility in which larger than expected water level depression in the core was experienced with accompanying fuel heat up as a result of liquid hold-up in other parts of the primary system.

70. TITLE: ROSA IV DATA ANALYSIS
CONTRACTOR: Los Alamos National Laboratory

	FY 85	FY 86	FY 87
BUDGET	220	650	700

OBJECTIVE:

To confirm the ability of NRC's safety analysis codes to predict safety system performance during transients and accidents by validating the code against data from large scale integral test facilities.

71. TITLE: COOP PROGRAMS SUPPORT
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	500	300	500

OBJECTIVE:
To provide support, advice and transfer of national laboratory technology to industry cooperative programs to ensure that these programs meet their regulatory objectives (see discussion under B3014, BWR FIST, and B8252, MB-2). Audit cooperative programs to address potential conflict-of-interest questions since the reactor vendors are parties to the cooperative ventures.

72. TITLE: SEMISCALE PROGRAM
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	4581	3146	500

OBJECTIVE:
As needed to resolve NRC concerns with plant safety and with licensing concerns in Westinghouse and Combusion Engineering plant designs, perform integral systems transient and loss of coolant accident tests and evaluate the data generated from these tests. Provide data for validation of computer codes used for reactor licensing safety evaluations by NRC staff. Uncertainties in the ability of best-estimate codes to predict response to these transients and accidents must be quantified as a basis for assessing the adequacy of conservatisms used in licensing-type codes. In this way the NRC staff can independently assess vendor and utility approaches to plant design and operations to assure safe response of the reactors to these events. During its lifetime, Semiscale has provided data for uncertainty assessment on essentially every loss of coolant accident and transient type of interest to the NRC staff.

73. TITLE: NRC/DAE DATA BANK
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	75	400	400

OBJECTIVE:
The regulatory purpose is to preserve the results of safety tests performed in experimental facilities and reactors. These safety tests were performed for regulatory purposes in the U.S.A. and worldwide. The test results could become inacessible after an experiment is dismantled. Hence, the Experimental Data Bank preserves and provides rapid access in a common easy to use format for all the safety tests. The safety tests data are needed to test and verify computer codes used for licensing analyses.

74. TITLE: SG TUBE RUPTURE
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	155	200	190

OBJECTIVE:
To experimentally determine the partition of iodine between liquid and steam in an environment which simulates steam generator tube rupture.

75. TITLE: MIXING IN STRATIFIED FLOWS
CONTRACTOR: UC-SB

	FY 85	FY 86	FY 87
BUDGET	85	254	200

OBJECTIVE:
(1) Develop simplified accurate methods to analyze thermal mixing in reactors and perform analyses in support of the Pressurized Thermal Shock (PTS) rule.
(2) Obtain boron mixing data needed for boron transport model development.

76. TITLE: MODELING OF TWO-PHASE FLOW
CONTRACTOR: Argonne National Lab

	FY 85	FY 86	FY 87
BUDGET	310	240	300

OBJECTIVE:
To develop two-phase flow models and correlations to support accurate LWR safety analyses and to assess scaling compromises in experimental facilities.

77. TITLE: CRIT DISCHARGE THRU PIPE CRACK
CONTRACTOR: Lawrence Berkeley Lab

	FY 85	FY 86	FY 87
BUDGET	80	75	0

OBJECTIVE:
To remove uncertainties in determining:
a. critical discharge through pipe cracks, and
b. critical flow through small-breaks in horizontal pipes with stratified upstream conditions by providing test data and validated models.

78. TITLE: NONEQUIL HEAT TRANSFER
CONTRACTOR: Lehigh University

	FY 85	FY 86	FY 87
BUDGET	85	100	0

OBJECTIVE:
To develop an experimentally and phenomenologically based model for thermal non equilibrium post Critical Heat Flux (CHF) heat transfer model applicable to both high and low flow rates in rod bundles.

79. TITLE: GEOMETRIC ANAL OF ENSEMBLE OF SOL - 2 PHASE FLOWS
CONTRACTOR: Brown University

	FY 85	FY 86	FY 87
BUDGET	50	80	0

OBJECTIVE:
a. To complete the resolution of the choking flow problem by conducting a geometric analysis of two-phase flow solutions.
b. To establish a choked flow criterion and validate it against available experimental data.

80. TITLE: DATA ANALYSIS & TESTS OF CORR		FY 85	FY 86	FY 87
CONTRACTOR: Undes Laboratory	BUDGET	0	50	0

OBJECTIVE:

To explore the feasibility of synthesizing and generalizing experimental data and code calculation results via appropriate similarity groups and/or similarity functions. To date, experiments and/or code calculations are performed by varying one parameter at a time, for example, by varying break size or power or emergency core cooling (ECC) water, etc. Similarly, for each run the results are presented as plots of single variables versus time, for example, pressure or break flow or T clad are plotted versus time. As a result, a large number of test runs and/or of code calculations and required in order to assess the effects of the various parameters of interest. If this program demonstrates that syntheses of experimental data and/or of calculated results are feasible, then this program will yield methods for achieving considerable savings in funds by reducing the number of required experimental tests and/or of code calculations.

81. TITLE: CODE ASSESSMENT & APPL (A1205)		FY 85	FY 86	FY 87
CONTRACTOR: Sandia National Lab	BUDGET	525	425	300

OBJECTIVE:

As part of the TRAC-PWR assessment effort.

82. TITLE: CODE ASSESSMENT & APPL		FY 85	FY 86	FY 87
CONTRACTOR: Brookhaven National Lab	BUDGET	225	200	150

OBJECTIVE:

The objectives are 1) to assess thermal & hydraulic system transient codes TRAC-BWR and RAMONA III B using domestic test data to assure the accuracy of the codes and to quantify the uncertainties of code predictions. The regulatory goal is to provide NRR with assessed computer codes so that vendor submittals of reactor transient analyses and operator guidelines can be audited.

83. TITLE: CODE ASSESSMENT & APPL		FY 85	FY 86	FY 87
CONTRACTOR: Idaho National Engineering Laboratory	BUDGET	435	0	300

OBJECTIVE:

The objectives are 1) to assess thermal & hydraulic system transient codes (TRAC-PF1/MOD1, TRAC-BD1/MOD1 and TRAC-BF1) using domestic test data to assure the accuracy of the codes, 2) to quantify the uncertanties of code predictions and 3) to perform transient analyses to resolve licensing issues. The regulatory goal is to provide NRR with assessed computer codes so that vendor submittals on reactor transient analyses and operator guidelines can be independently audited.

84. TITLE: USER ASSISTANCE FOR CODE EXCHANGE
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	350	1200	850

OBJECTIVE:
The objectives are 1) to assess thermal & hydraulic system transient codes RELAPS/MOD2, TRAC-BWR using foreign results and domestic data to 1) assure the accuracy of the codes: 2) quantify the uncertainty of code predictions and 3) perform plant transient analyses. The regulatory goal is to provide NRR with assessed computer codes so that licensee submittals on reactor transient analyses and operator guidelines can be audited and reviewed, and operating transients can be reviewed and assessed.

85. TITLE: USER ASSISTANCE FOR CODE EXCHANGE
CONTRACTOR: Los Alamos National Laboratory

	FY 85	FY 86	FY 87
BUDGET	350	685	450

OBJECTIVE:
The objectives are 1) to assess thermal & hydraulic system transient code TRAC-PF1/MOD1 using foreign results and domestic data to: 1) assure the accuracy of the codes; 2) quantify the uncertainty of code predictions; and 3) perform plant transient analyses. The regulatory goal is to provide NRR with assessed computer codes so that license submittals on reactor transient analyses and operator guidelines can be reviewed and audited and operating transients can be reviewed and assessed. Resolves uncertanties associated with noding sensitivities in B&W reactor thermal hydraulic behavior predictions with TRAC-PF1/MOD1.

86. TITLE: THERMAL REACTOR SAFETY CODE DEVELOPMENT
CONTRACTOR: Brookhaven National Laboratory

	FY 85	FY 86	FY 87
BUDGET	50	50	100

OBJECTIVE:
The objective is to provide NRR with a system transient Boiling Water Reactor thermal & hydraulic analysis code (RAMONA III B) with three dimensional neutron kinetics capability so that vendor submittals on reactor transient analyses and operator guidelines can be audited.

87. TITLE: DEVELOPMENT OF PLANT ANALYZER
CONTRACTOR: Brookhaven National Laboratory

	FY 85	FY 86	FY 87
BUDGET	150	150	200

OBJECTIVE:
The objective is to provide NRR with a fast running system transient (not including LOCA) Boiling Water Reactor thermal & hydraulic analysis code (HIPA) on a stand-alone parallel processing computer so that vendor submittals on reactor transient analyses and operator guidelines can be audited quickly.

88. TITLE: CODE DEVELOPMENT & IMPROVEMENT CONTRACTOR: Idaho National Engineering Laboratory		FY 85	FY 86	FY 87
	BUDGET	656	885	500

OBJECTIVE:

To provide NRR the capability to accurately analyze a wide variety of PWR transients for use in auditing vendor calculations of ECCS behavior under Loss-of-Coolant Accident conditions defined 10 CFR 50.46 Appendix K, and reviewing operator procedures. Develop a code to be used to perform sensitivity study on paramters (such as decay heat, break flow, etc.,) which affect fuel peak clad temperature.

89. TITLE: RELAP 5 CONTRACTOR: Idaho National Engineering Laboratory		FY 85	FY 86	FY 87
	BUDGET	150	0	200

OBJECTIVE:

To provide NRR the capability to accurately calculate a wide variety to PWR transients for use in auditing vendor calculations of ECCS behavior under Loss-of-Coolant-Accident conditions defined 10 CFR 50.46 Appendix K, and reviewing operator procedures. Develop a code to be used to perform sensitivity study on parameters (such as decay heat, break flow, etc.,) which affect fuel peak clad temperature.

90. TITLE: PLANT ANALYZER CONTRACTOR: Idaho National Engineering Laboratory		FY 85	FY 86	FY 87
	BUDGET	533	575	700

OBJECTIVE:

The objective is to assist NRR in auditing licensee application and performance. The regulatory goal is to make swift decisions on the safe operation of a plant where an operational transient has occurred (and similar plants). This requires speed up of the computer program used for analysis, making input to the programs easier and making program output more quickly comprehensible by translating thousands of numerical values into pictures.

91. TITLE: TRAC CODE DEVELOPMENT CONTRACTOR: Los Alamos National Laboratory		FY 85	FY 86	FY 87
	BUDGET	500	500	500

OBJECTIVE:

To maintain the best estimate advanced TRAC-PWR code (thermal-hydraulic code for Pressurized Water Reactors) in order to respond to licensing issues such as: (1) best estimate LOCA calculations to determine the available margins in vendor calculations of plant behavior under LOCA and transient conditions, (2) resolution of issues involving decay heat removed using feed and bleed procedures, and (3) evaluation of operator guidelines. Calculations using TRAC-PWR allow resolution of uncertainties regarding the ability of the reactor safety systems to prevent fuel damage during these transient conditions and accidents. Some of the specific uncertainties are critical heat flux, heat transfer following critical heat flux and coolant flow distribution during reactor blowdown.

92. TITLE: PLANT ANALYZER
CONTRACTOR: Los Alamos National Laboratory

	FY 85	FY 86	FY 87
BUDGET	750	500	700

OBJECTIVE:
The objective is to assist NRR in auditing licensee applications and performance. The regulatory goal is to make swift decisions on the safe operation of a plant where an operational transient has occurred (and similar plants). This requires speed up of the computer program used for analysis, making input to the programs easier and making program output more quickly comprehensible by translating thousands of numerical values into pictures.

93. TITLE: COBRA MAINTENANCE
CONTRACTOR: Pacific Northwest Laboratories

	FY 85	FY 86	FY 87
BUDGET	79	15	100

OBJECTIVE:
To maintain the COBRA-TRAC and COBRA-FS thermal-hydraulic codes for pressurized water reactors with specific ability to calculate two phase flow mechanistically and to handle complex geometries in order to respond to licensing issues. The codes should be able to perform best estimate loss-of-coolant-accident (LOCA) predictions (especially for Westinghouse plants with Upper Head Injection) to determine the available margins in vendor calculation, and to evaluate operator guidelines, and should be able to perform detailed sub-channel behavior calculation for the reactor core.

94. TITLE: NUCLEAR REACTOR PLANT DESCRIPTION DATA BANK
CONTRACTOR: Technology Develop Corp.

	FY 85	FY 86	FY 87
BUDGET	30	65	0

OBJECTIVE:
Serve as a computer bank of plant reactor geometric and operating data, sufficient for thermal hydraulic reactor safety analyses. Provide automated tools to permit rapid renodelization and creation of input decks to NRCs safety analysis computer codes. Train potential users to input data and perform input deck creations. Assist with User Acceptance Testing of the software.

C. ACCIDENT EVALUATION DECISION UNIT

95. TITLE: SEVERE ACCIDENT SEQUENCE ANALYSIS-PWRS
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	825	600	600

OBJECTIVE:
Apply deterministic analyses to risk dominant accident sequences for specific plants utilizing best estimate values. Improve our understanding on severe accidents by defining operator actions which can reduce core melt likelihood or mitigate its consequences and provide assessment of the adequacy of proposed operational guidelines for coping with transients that challenge plant safety. Provide mechanistic analyses of containment loading from severe accidents and the resulting threats to safety equipment.

96. TITLE: BWR SEVERE ACCIDENT ANALYSIS
CONTRACTOR: Sandia National
Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	240	0

OBJECTIVE:
Apply deterministic analyses to risk dominant accident sequences for specific plants utilizing best estimate values. Improve our understanding of severe accidents by assuring development of ex-vessel core/concrete interaction models to be fully reapresentative of BWR plants. Provide mechanistic analysis of containment loading from severe accident and the resulting threats to safety equipment.

97. TITLE: SEVERE ACCIDENT SEQUENCE
ANALYSIS-PWRS
CONTRACTOR: Idaho National Engineering
Laboratory

	FY 85	FY 86	FY 87
BUDGET	825	800	650

OBJECTIVE:
Perform realistic analyses for risk dominant accident sequences for specific plants utilizing best-estimate values in deterministic analysis codes. Improve understanding of potential severe reactor accidents by i) defining operator action which can reduce core melt likelihood or mitigate its consequences and ii) providing an assessment of the adequacy of proposed operational guidelines for coping with transients that challenge a plants safety.

98. TITLE: SEVERE ACCIDENT ANALYSIS-BWRS
CONTRACTOR: Idaho National
Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	150	0

OBJECTIVE:
Perform realistic analyses for risk dominant accident sequences for specific plants utilizing best-estimate values in deterministic analysis codes. Improve understanding of potential severe reactor accidents by i) defining operator action which can reduce core melt likelihood or mitigate its consequences and ii) providing an assessment of the adequacy of proposed operational guidelines for coping with transients that challenge a plants safety.

99. TITLE: METH SAFETY ANALYSIS
CONTRACTOR: Los Alamos National
Laboratory

	FY 85	FY 86	FY 87
BUDGET	400	475	0

OBJECTIVE:
The SIMMER-II computer code was developed to provide a tool to analyse hypothetical core disruptive accidents (HCDA) in liquid metal fast breeder reactors. The code calculates the energetics of HCDS's and their potential threat to the reactor vessel and containment. The objective of ongoing work is to make improvements to the running time of the code to reduce costs and to apply the code to analysis of safety problems. Continued cooperation with KFK of West Germany, CEA of France and PNC of Japan will maintain access to experimental data from foreign fast breeder research programs.

100 TITLE: SEVERE ACCIDENT SEQUENCE ANALYSIS-PWRS
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	1004	850	650

OBJECTIVE:

Apply deterministic analyses to risk dominant accident sequences for specific plants utilizing best estimate values. Improve understanding of severe accidents by defining operator actions which can reduce core melt likelihood or mitigate its consequences and provide assessment of the adequacy of proposed operational guidelines for coping with transients that challenge plant safety. Assure that methodology developed primarily for PWR analysis includes adequate modification of BWR plant studies.

101 TITLE: FP TRANSPORT IN BWR SEVERE ACCIDENTS
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	100	0

OBJECTIVE:

Apply deterministic analyses to risk dominant accident sequences for specific plants utilizing best estimate values for fission product tracking. Improve understanding of severe accidents by defining operator actions which can reduce the source term to the environment and the offsite consequences. Assure that methodology developed primarily for PWR analysis includes an adequate data base for BWR plant studies.

102 TITLE: ACRR MELT PROG EXPRTS
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	975	1000	1400

OBJECTIVE:

To develop a data base and validated analytical models on the governing processes in the development of severe fuel damage (including the oxidation process and hydrogen generation), core-melt progression (including control-rod effects), and in-vessel fission-product and aerosol release for the range of LWR severe accident conditions by performing small-scale integral experiments in the Annular Core Research Reactor (ACRR). The results are used to assess and improve severe-accident analysis codes, in particular the mechanistic MELPROG melt-progression and SCDAP fuel-damage codes. This program includes four fresh-fuel Debris Formation (DF) experiments, two with control-rods, to be completed in FY 86, and two follow-on Melt Progression and Source Term (MPST) experiments with high burnup fuel up to fuel-melt temperatures for a PWR and a BWR risk-dominant accident sequence that are to be performed in FY 87. This program is part of the joint international Severe Fuel Damage (SFD) and Source Term (ST) research program of the Fuel Systems Research Branch.

103 TITLE: MELPROG CODE DEVELOPMENT
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	565	800	600

OBJECTIVE:

1. Develop a best-estimate computer code (joint work with FIN A7303) MELPROG, to analyse severe accidents from core melt to reactor vessel failure.
2. Apply the code to predict the timing and the characteristics of the release of core debris and radioactive materials to the containment.

104 TITLE: MELPROG VALIDATION EXPTS
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	1200	1300

OBJECTIVE:

To provide a technical basis for validation of the MELPROG mechanistic in-vessel core-melt progression code by assessing the uncertainties in the governing process and by providing a much stronger validation data base by experiments to reduce the risk-dominant uncertainties. Because of the large scale and complex interactions involved, a large-scale integral validation proof test of MELPROG is not feasible. Key individual elements of the code are to be validated by experiment with integration of the elements of necessity by analysis with some relevant integration data furnished by the TMI-2 core examination. Areas requiring new experimental data include: core-debris relocation, the thermal attack on the core-support structure and the reactor vessel, the node of vessel failure, the effects of control rod materials, and the effects of multi-dimensional natural convection and heat transfer. These are to be addressed by a program of separate-effect experiments, out-of-pile in the laboratory and in existing test facilities, and in-pile in ACRR.

105 TITLE: TMI FUEL EXAM
CONTRACTOR: Argonne National Laboratory

	FY 85	FY 86	FY 87
BUDGET	200	300	300

OBJECTIVE:

By examination of the TMI-2 core debris, to provide benchmark data for the assessment of severe accident codes and for augmentation of results of the Severe Fuel Damage and Source Term research program.

106 TITLE: COMMIX CALCULATIONS
CONTRACTOR: Argonne National Laboratory

	FY 85	FY 86	FY 87
BUDGET	150	100	0

OBJECTIVE:

To predict multi-dimensional flow patterns and temperature distributions in the reactor coolant system of a pressurized water reactor (PWR) during high-pressure transients.

107 TITLE: MELCOR BENCHMARKING
CONTRACTOR: Brookhaven National
Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	200	500	600

OBJECTIVE:

To ensure that models developed for MELCOR are adequate for source term analysis, and to perform benchmark analyses and code verification for the complete MELCOR code.

108 TITLE: PBF STANDBY OPERATIONS
(POST FY 85)
CONTRACTOR: Idaho National
Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	6530	500	0

OBJECTIVE:

In FY 86 to provide for minimum cost standby operation of Power Burst Facility until FY 87. When funds for deactivation will become available.

109 TITLE: RESIDENT SCIENTIST AT
KFK, FRG
CONTRACTOR: Idaho National
Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	100	60	200

OBJECTIVE:

To facilitate the exchange of nuclear safety-related information between the U.S. and Germany. Germany provides in-kind research as its contribution under the Severe Fuel Damage International Agreement.

110 TITLE: SEVERE FUEL DAMAGE MODEL DEV
CONTRACTOR: Idaho National
Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	700	770	650

OBJECTIVE:

1. Develop and validate a best-estimate computer code (SCDAP) to analyze recovered or mitigated severe accidents from initial core damage to accident recovery.
2. Apply this (SCDAP) code to predict the timing and magnitude of radioactive material and hydrogen release to the containment or to other areas outside the reactor coolant system during recovered severe accidents.

111 TITLE: TRAC/MELPROG INTEGRATION
CONTRACTOR: Los Alamos National Laboratory

	FY 85	FY 86	FY 87
BUDGET	320	300	350

OBJECTIVE:

1. Develop the best-estimate computer code (joint work with FIN A1342) MELPROG, to analyze severe accidents from core melt to reactor vessel failure.
2. Apply the code to predict the timing and the characteristics of the release of core debris and radioactive materials to the containment.

112 TITLE: SEVERE CORE DAMAGE MATERIALS PROP TEST
CONTRACTOR: Pacific Northwest Laboratories

	FY 85	FY 86	FY 87
BUDGET	290	300	200

OBJECTIVE:

To obtain high temperature data on core material behavior for use in severe core damage fuel behavior irradiation tests, for safety analysis codes, and for analysis of the severe fuel damage research program results. Uncertainties in reactor core materials properties under severe accident conditions affect fission product release analyses in two ways. The chemical interactions calculations, which require accurate material properties input, yield radionuclide chemical states. These are needed for health effects determinations. The second effect of accurate materials properties data is on fuel mitigative actions to cool a damaged core.

113 TITLE: MOLTEN CORE-COOLANT INTERACTIONS
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	1100	585	0

OBJECTIVE:

To study the interaction of molten core material with water in order to develop a fundamental understanding of the governing phenomena and to measure the mechanical energy released from a corium-coolant interaction during a severe accident in a light water reactor. Provide analytical methods and computer codes to predict the mechanical energy produced, hydrogen generation rate, coarse mixing, and debris characteristics resulting from corium-coolant interactions.

114 TITLE: CONTAINMENT ANALYSIS
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	1050	800	1200

OBJECTIVE:

To develop and implement a computer program (CONTAIN) to model power-reactor containment systems and to predict the thermal, physical, and chemical loads imposed by accident conditions.

115 **TITLE:** CORE MELT TECHNOLOGY
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	2000	1450	1500

OBJECTIVE:

In severe reactor accidents in which molten core material escapes the reactor pressure vessel and falls into the reactor cavity, thermal and chemical interactions between the high-temperature core debris and structure concrete are expected to ensure. The purpose of this project is to design and conduct experiments to study the thermal and chemical phenomena expected to characterize these core-concrete interactions.

116 **TITLE:** HYDROGEN BEHAVIOR PROGRAM
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	1310	1200	200

OBJECTIVE:

To provide the NRC with the basis to quantify the threat to nuclear power plants containment structure, safety equipment and the primary system posed by hydrogen combusion.

117 **TITLE:** DIRECT CONTAINMENT HEATING
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	650	700

OBJECTIVE:

The objective of this program is to investigate consequences of high pressure melt ejection. In certain accident scenarios, the reactor vessel may remain pressurized when the molten core materials breaches the bottom of the reactor vessel. When the melt is ejected under pressure into the containment, it is likely to be dispersed as fine particles and heat the containment atmosphere by thermal and chemical interactions producing high static and dynamic loading on the containment. A large amount of aerosols, including refractory radioactive fission products, could be generated so that is the containment should fail from the DCH loading, massive release of fission products could result. Results of this experimental program will provide data basis for quantitative assessment of the consequences of this potentially high risk event.

118 **TITLE:** QUANT UNCERTAIN OF CONTAINMENT LOADING
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	200	0

OBJECTIVE:

Evaluate uncertainties in quantitative predications of loading on reactor containments for selected severe accident sequences at specific plants.

119 TITLE: ICE CONDENSER MSLB ANALYSIS MTHDS (MAIN STEAM LINE BREAK)
CONTRACTOR: Argonne National Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	150	0

OBJECTIVE:

Develop and implement the necessary models in the COMMIX code to investigate the mixing phenomena and temperature behavior in the lower compartment of an Ice Condenser PWR during a postulated main steam line break accident using a three dimensional simulation.

120 TITLE: CORIUM-COOLANT MIXING
CONTRACTOR: Argonne National Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	865	0

OBJECTIVE:

To study the mixing of corium with water in order to develop a fundamental understanding of the governing phenomena during a severe accident in a light water reactor. Provide analyses of the mechanical energy produced, hydrogen generation rate, amount of breakup and mixing, depth of mixing, quench rate, and debris characteristics resulting from corium-coolant interactions.

121 TITLE: THERMAL HYDRAULIC EXP
CONTRACTOR: Brookhaven National Laboratory

	FY 85	FY 86	FY 87
BUDGET	750	450	000

OBJECTIVE:

Perform experiments, together with corresponding model development, to improve understanding of thermal-hydraulic phenomena involved in severe accident high-temperature core debris behavior.

122 TITLE: THERMAL HYDRAULICS-CORE/CONCRETE INTERACTIONS
CONTRACTOR: Brookhaven National Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	290	0

OBJECTIVE:

Conduct experiments together with analysis and model development on the thermo-dynamic phenomena that govern the interactions between reactor core debris and concrete as well as evolution of aerosols and fission products from debris pool.

123 TITLE: HYDROGEN MIGRATION & MIXING STUDIES
CONTRACTOR: Los Alamos National Laboratory

	FY 85	FY 86	FY 87
BUDGET	250	175	100

OBJECTIVE:

To develop a three-dimensional code for the analysis of hydrogen distribution and combustion under severe accident conditions. The code will provide the capability to analyze hydrogen diffusion flames, sepcifically to assess the impact of the flames on safety related equipment.

124 TITLE: AEROSOL RELEASE & TRANSPORT
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	1300	1000	1000

OBJECTIVE:

Perform designed experiments to investigate phenomena affecting the behavior of aerosols within containment over a range of light water reactor severe accident conditions. Develop a data base for the assessment of existing analytical models and codes that will accurately predict the behavior of aerosols within LWR containments.

125 TITLE: COBRA APPLICATIONS (b2391)
CONTRACTOR: Pacific Northwest Laboratory

	FY 85	FY 86	FY 87
BUDGET	250	55	400

OBJECTIVE:

The objective of this program is to develop a finite-difference, advanced containment analysis code that can benchmark simpler lump-parameter codes and analyze problems which these lump-parameter codes are unable to deal with.
Examples of such problems are:

- o Design basis accident - subcompartment differential pressure, reactor cavity pressurization, ice condenser drain water mixing, etc.
- o Severe accident - combustible gas mixing and transport, aerosol transport inside containment.

Typically, the analysis of these problems require the capability to calculate the motion and conditions of different species and/or phases of the fluid mixture. This cannot be accomodated by the lump-parameter code with a well mixed assumption.

126 TITLE: HIGH TEMP FISSION PROD CHEM
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	450	400	400

OBJECTIVE:

To provide data for development of fission product transport models to enable best-estimate consequence calculations for the retention of fission products in the reactor coolant system in a severe accident. Specifically, to investigate, following release from the fuel, the high temperature chemistry of fission products in the vapor phase and the chemical interaction of fission products with structural surface materials and airborne aerosols.

127 TITLE: ACRR SOURCE TERM EXPTS

CONTRACTOR: Sandia National Laboratory		FY 85	FY 86	FY 87
	BUDGET	800	1500	1800

OBJECTIVE:

To develop a data base on the in-vessel fission-product and aerosol release rates from reactor fuel and on fission product and aerosol chemical form for core-uncovery-accident conditions including temperatures up to fuel melt, a range of pressure, and a range of conditions of fuel liquifaction and thermo-chemical environment. A series of seven separate-effects Source Term (ST) experiments will be performed in the Annular Core Research Reactor (ACRR) test reactor in precisely controlled in-core environments to provide these data. This research is part of the integrated Severe Fuel Damage and Source Term research program of the NRC and its foreign program partners, who have furnished the majority of the program funding.

128 TITLE: FUEL FP REL FASTGRASS CODE

CONTRACTOR: Argonne National Laboratories		FY 85	FY 86	FY 87
	BUDGET	800	250	150

OBJECTIVE:

To develop a mechanistic fission product release model (the FASTGRASS code) for best-estimate source term calculations for the NRC licensing staff. The code should describe fission product release from LWR fuels during thermal transients and severe reactor accidents and should be developed based on experimental results obtained from other NRC sponsored programs on the area of fission product release.

129 TITLE: POST TEST FUEL EXAM

CONTRACTOR: Argonne National Laboratories		FY 85	FY 86	FY 87
	BUDGET	150	150	0

OBJECTIVE:

To provide information on fission product release mechanisms for use in developing detailed models of fission product release from fuel in severe core melt accidents by conducting post-test examinations of the commercially irradiated fuel rods specimens subjected to high temperature fission product release testing at ORNL.

130 TITLE: UNCERTAINTY ANALYSIS OF SOURCE TERM

CONTRACTOR: Brookhaven National Laboratory		FY 85	FY 86	FY 87
	BUDGET	83	800	600

OBJECTIVE:

(1) Perform a systematic evaluation of the input parameters on phenomenological models in the Source Term Code Package (STCP) to define reasonable, technically defensible ranges and assumptions for use in the STCP).

(2) Determine the uncertainty in the source term to the containment for selected sequences at two of the five reference plants studied by the NRC's Assitent Source Term Program Office (ATPO) in order to evaluate conformance to NRC severe accident policy.

131 TITLE: PBF EXPT PGM
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	2923	1950	2000

OBJECTIVE:

To provide a data base for mechanistic models on the development of severe fuel damage, under the core-uncovery conditions of severe accidents in Light-Water Reactors (LWRs), by performing integral multi-rod fuel-bundle tests in the Power Bust Facility test reactor, analysis of the test results, and by model development and assessment. Fission-product release and transport, hydrogen generation and temperature distributions during the test transients are measured, with post-test characterization of test fuel debris, including core-melt progression, made by neutron radiography and tomography and by Post-Irradiation Examination (PIE). This program is part of the integrated Severe Fuel Damage and Source Term research program of the NRC and its foreign program partners.

132 TITLE: PBF FISSION PRODUCT STUDIES
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	1884	950	1000

OBJECTIVE:

1. To investigate fission product release, transport and behavior under proto-typic accident conditions.
2. To collect, analyze, and report fission product release and transport data from the Severe Fuel Damage (SFD) tests.
3. To measure magnitude, timing, release tules, chemical forms, transport and deposition of fission products released in in-pile Tests.

133 TITLE: FP RELEASE AT SEVERE ACCIDENT CONDITIONS
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	1460	1300	850

OBJECTIVE:

To provide an experimental data base for developing fission product release models to enable best-estimate source term calculations in the fission product release area in severe accidents. Specifically, to investigate experimentally uncertainties in the magnitude and physiochemical form of fission products released and control rod failure behavior under the elevated temperature and environmental conditions characteristic of severe fuel damage and core melt accidents.

134 TITLE: POST ACCIDENT FISS PROD CHEM
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	300	300	200

OBJECTIVE:

To determine the aqueous and vapor phase chemistry of fission products in the containment under representative reactor accident conditions and to model the findings in mathematical formulations to facilitate best-estimate source term calculations.

135 TITLE: TRAP-MELT VERIFICATION PGM
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	300	300	300

OBJECTIVE:
To provide data for the assessment of the TRAP-MELT primary system transport and deposition code which enables the NRC regulatory staff to have best-estimate consequence calculations done to determine the retention of fission products and aerosols in the reactor coolant system in a severe accident. Specifically, to conduct small scale aerosol transport tests and resuspension tests. The former will provide data to be compared to TRAP-MELT calculations, with the final aim of assessing the code's aerosol transport models. The latter will provide data for the development of an aerosol resuspension model that can be incorporated in TRAP-MELT and other aerosol transport codes.

136 TITLE: MARVIKEN ATT SUPPORT
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	135	25	0

OBJECTIVE:
Provide technical support for the large fission product and aerosol tests in the MARVIKEN facility (Sweden) as needed to identify uncertainties in the quantities and form in which fission product aerosols might be released to the public.

137 TITLE: NRU COOLANT BOILAWAY & DAMAGE PROGRESSION TESTS
CONTRACTOR: Pacific Northwest Laboratories

	FY 85	FY 86	FY 87
BUDGET	1992	2000	2700

OBJECTIVE:
To obtain data for full-length coolant boildown tests in NRU on in-reactor fission product release and transport, hydrogen release, and fuel relocation for computer code verification, for implementation of the NRC Severe Accident Policy Statement, for emergency planning, and for establishing siting policy.

138 TITLE: SUPPORT SERVICES FOR SEVERE ACCIDENT ANALYSIS
CONTRACTOR: Battelle Columbus Laboratories

	FY 85	FY 86	FY 87
BUDGET	1902	1140	0

OBJECTIVE:
Provide a source of expertise and analysis capability which can be called upon by RES to perform research and evaluation of severe accident phenomena. Assist NRC in expeditiously developing a revised source term and severe accident policy statement. Provide integrating assistance to NRC with regard to the severe accident research program.

D. REACTOR OPERATIONS AND RISK

139 TITLE: EFFICIENT PROB COMPUTATIONS & METHODS/PRA
CONTRACTOR: Lawrence Livermore National Lab

	FY 85	FY 86	FY 87
BUDGET	225	90	0

OBJECTIVE:

Existing PRA methods and procedures lack internal consistency, are incomplete in terms of their treatment of common-cause failures (e.g., external events, human reliability) and, as a result, produce results with large uncertainties. These inadequacies have severely limited the usefulness of PRAs in guiding and supporting a broad range of Commission decisions and actions, e.g., in the areas of safety issue isolation, backfitting, implementation of safety goal and severe accident policies. The objective of this project is to assess and develop a quantification technique that will be used for calculating system reliability characteristics when the rare event approximation does not hold, to investigate extensions of the fault graph method, and to investigate and refine cut set generation algorithms.

140 TITLE: INTEGRATED DEPENDENT FAILURE METHODOLOGY
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	275	285	250

OBJECTIVE:

Existing PRA methods and procedures lack internal consistency, are incomplete in terms of their treatment of common-cause failures (e.g., external events, human reliability) and, as a result, produce results with large uncertainties. These inadequacies have severely limited the usefulness of PRAs in guiding and supporting a broad range of Commission decisions and actions, e.g., in the areas of safety issue isolation, backfitting, implementation of safety goal and severe accident policies. The objective of this project is to develop an integrated methodology for the identification, quantification, and assessment of the impact of dependent failures upon system failures and accident sequence occurrences. The methods will address location-dependent common causes that can link events in system models by location and susceptibility to generic environments as well as common causes that transcend locations such as maintenance and operator actions.

141 TITLE: RISK METHODOLOGY INTEGRATION & EVAL PGM (RMIEP)
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	900	545	425

OBJECTIVE:

To provide RNN information needed in areas of external events, human factors, plant analysis and containment analysis, RMIEP will:

- o Integrate internal, external, and dependent failure risk methods to achieve greater efficiency, consistency, and completeness in risk assessments;
- o Evaluate Probabilistic Risk Analysis (PRA) technology developments and lay the basis for improved PRA procedures;
- o Identify, evaluate, and effectively display the uncertainties in PRA risk predictions which stem from limitations in plant modeling, PRA methods, or data;
- o Conduct a PRA on Boiling Water Reactor (BWR 5). Mark II nuclear plant (La Salle Unit 2), ascertain the plant's dominant sequences, and formulate the results to make it possible to easily update the PRA and to allow testing of future improvements in methodology, data, and the treatment of phenomena.

142 TITLE: FIRE RISK ANALYSIS APPLICATION
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	210	50	50

OBJECTIVE:

The objective of this program is to perform a probabilistic analysis of the occurrance frequency and severity of fire accident scenarios for the Risk Methodology Integration and Evaluation Program (RMIEP), using the state-of-the-art fire risk analysis modelling techniques. Existing analytic techniques have large uncertainties, lack internal consistency, and are incomplete in treatment of major failure mechanisms. These inadequacies severely limit the application of PRA to safety goal decisions, plant-specific examination of generic safety issues, and the synergistic considerations necessary for prudent regulation. The objective of this program is to provide for these problems a set of solutions which are complete, integrated, and tested.

143 TITLE: INTEGRATED PRA SOFTWARE DEV
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	200	200	100

OBJECTIVE:

The objective of the program is to provide computer tools for systematically performing reliability and risk studies and assessing the uncertainties in them. This will help provide a more uniform and consistent treatment of uncertainties in regulatory and reliability analyses.

Design the software system including development of analytical techniques, evaluate and integrate existing techniques to meet the needs identified in the PRA software plan, identify techniques and existing software, and develop software where needed. In addition this program will develop integrated software which includes capabilities to treat dependent failures and external events in a consistent manner.

144 TITLE: SYSTEM ANAL & RISK ASSESS SYSTEM (SARA)
CONTRACTOR: Idaho National Engineering Lab

	FY 85	FY 86	FY 87
BUDGET	250	250	200

OBJECTIVE:
Develop a capability for computation and analysis of information on NPP risk characteristics, using state-of-the-art, user-friendly and modularized computer software and existing NPP risk information developed under current programs. The purpose is primarily to assist the CRGR in tracking the progress that required/proposed plan modifications did/will make toward improved safety levels. In addition, the SARA system is to be designed as a flexible tool to support different levels of users requiring risk and reliability information for decisionmaking and regulatory analysis.

145 TITLE: HRA RESULTS UTILIZATION FOR USI/GSI RESOLUTION
CONTRACTOR: Brookhaven National Lab

	FY 85	FY 86	FY 87
BUDGET	330	205	250

OBJECTIVE:
Existing probabilistic risk assessment (PRA) methods and procedures lack internal consistency, are incomplete in terms of their treatment of common cause failure (e.g., external events, human reliability) and, as a result, produce results with large uncertainties. These inadequacies have severely limited the usefulness of PRAs in guiding and supporting a broad range of Commission decisions and actions, e.g., in the areas of safety issue isolation, backfitting, implementation of safety goals and severe accident policies. The objective of this research is to develop and field evaluate/validate methods and techniques for systematically using human reliability analysis (HRA) data from PRAs and other human reliability or human factors sources, for supporting resolution of unresolved and Generic Safety Issues, and for identifying immediate and long-term human reliability and human factors research requirements consistant with NRC safety goals.

146 TITLE: HUMAN RELIABILITY ANAL FOR RMIPP
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	330	175

OBJECTIVE:

Begin with the Generic Objective. a) Identify, evaluate, and apply selected human reliability analysis inputs for probabilistic risk assessments, in support of the RMIEP program. b) Analyze selected accident sequences using more qualified human reliability analysis methods in order to predict the nature, frequency, duration and probability of significant human error contributions to the LaSalle PRA. c) Provide recommendations for future utilization of human reliability analysis methods in PRAs as an integrated element in the RMIEP program.

147 TITLE: HUMAN RELIABILITY DATA BOOK
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	250	200

OBJECTIVE:

Existing probabilistic risk assessment (PRA) methods and procedures lack internal consistency, are incomplete in terms of their treatment of common cause failure (e.g., external events, human reliability) and, as a result, produce results with large uncertainties. These inadequacies have severely limited the usefulness of PRAs in guiding and supporting a broad range of Commission decisions and actions, e.g., in the areas of safety issue isolation, backfitting, implementation of safety goals and severe accident policies. The objective of this research is to computerize and bring on-line a real-time human reliability data bank based on the technical specification presented in NUREG/CR-4010. This technical specification was the final milestone of an earlier NRC research program directed toward a data bank configuration capable of accepting human performance data from a wide variety of sources and collating and processing those data for use in reliability evaluations.

148 TITLE: COGNITIVE MODELING-NUC POWER STATIONS
CONTRACTOR: Westinghouse

	FY 85	FY 86	FY 87
BUDGET	152	250	275

OBJECTIVE:

Existing probabilistic risk assessment (PRA) methods and procedures lack internal consistency, are incomplete in terms of their treatment of commoncause failure (e.g., external events, human reliability) and, as a result, produce results with large uncertainties. These inadequacies have severely limited the usefulness of PRAs in guiding and supporting a broad range of Commission decisions and actions, e.g., in the areas of safety issue isolation, backfitting, implementation of safety goals and severe accident policies. The objective of this research is to develop and test improved methods and techniques for modeling the cognitive performance of selected NPP personnel, for use in reliability evaluation studies and programs, safety issue, resolution and related risk reduction initiatives of the NRC.

149 TITLE: REL EVAL BASE STUDY WITH EPRI
CONTRACTOR: Undes Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	50	0

OBJECTIVE:

Existing probabilistic risk assessment (PRA) methods and procedures lack internal consistency, are incomplete in terms of their treatment of common cause failure (e.g., external events, human reliability) and, as a result, produce results with large uncertainties. These inadequacies have severely limited the usefulness of PRAs in guiding and supporting a broad range of Commission decisions and actions, e.g., in the areas of safety issue isolation, backfitting, implementation of safety goals and severe accident policies. The objectives of this research is to conduct a field evaluation within the context of an Italian Joint Research Center Benchmark program, of selected human reliability analytic tools and procedures recently developed by the NRC and Electric Power Research Institute (EPRI). Utilizing a case study approach, this project will allow the NRC and EPRI to acquire comparative data on selected NRC and EPRI analytic tools/procedures and tools/procedures developed by other nations participating in the program.

150 TITLE: HUMAN FACTORS NEEDS IN RES
CONTRACTOR: NAS

	FY 85	FY 86	FY 87
BUDGET	0	131	0

OBJECTIVE:

With the termination of the NRC human factors research program at the end of FY 1985, except for participation in the international Halden Project, and consideration of the changing human factors function of NRR, NRC staff (RES and NRR), ACRS (May 13, 1985 letter to Commission), and the Commission (September 13, 1985 meeting), have determined that it would be highly beneficial to obtain an independent, unbiased, nonevaluative assessment of U.S. commercial nuclear power human factors research and applications accomplishments both inside and outside the NRC since the TMI-2 accident, and to identify broad areas where additional human factors research may be needed in the future to enhance plant safety. The objective of this project is to benchmark, make broad recommendations for future research.

151 TITLE: PRA UNCERTAINTIES
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	50	700	700

OBJECTIVE:

1. To perform an integrated uncertainty analysis (including the likelihood and consequences) of the ATWS class of accidents for the Peach Bottom plant.
2. Develop guidelines for incorporating accident likelihood uncertainties and physical process uncertainties into an overall risk uncertainty estimate, and for determining the principal contributors to this uncertainty. Perform core, containment, and consequence analyses for LaSalle being investigated in the RMIE (Risk Methods Integration and Evaluation) program using the MELCOR code system, in order to evaluate the central estimate consequences of accident sequences in that plant, the associated uncertainty, and the principal contributors to that uncertainty.

152 TITLE: ROOT CAUSE FAILURE ANALYSIS
CONTRACTOR: Idaho National
Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	150	185	0

OBJECTIVE:

Develop methodologies and provide demonstrations for utilization and interpretation of root causes of component failure information for plant aging, reliability assurance, inspection, and other regulatory applications.

153 TITLE: INTEGRATED RISK ANALYSIS DATA
ACQUISITION PROGRAM
CONTRACTOR: Idaho National Engineering Lab

	FY 85	FY 86	FY 87
BUDGET	200	250	0

OBJECTIVE:

A uniform, comprehensive and consistent set of data on failure rates for components and plant safety systems does not presently exist. Furthermore, the absence of data on the root causes of such failures severely limits the use of PRA in supporting regulatory decisions as well as in the development and implementation of inspection and reliability assurance programs applicable to NRC licensees. The objective of this project is to integrate existing data programs to obtain a coherent data base for use in risk assessments and collect and analyze additional data, as required.

154 TITLE: ANALYSIS OF RELIABILITY DATA
FROM NPPS (IPRDS)
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	500	300	0

OBJECTIVE:

Provide uniform, consistent nuclear component reliability data for use in NUREG 1150 and probabilistic risk assessments in general. Existing PRA data sources do not provide sufficient statistics for reliability and risk estimates with small uncertainties that are reasonably achievable. The lack of coordination and consistency among the various sources of data injects added uncertainty and variability in PRA results. Important data are lacking, such as fractions of root causes contributing to important component failure modes. Such data are vital to plant reliability programs and to use of PRA in the NRC inspection program. The objectives of these programs (A6831, A6393, B9445, A72225, and A1393) are to provide for identification of regulatory risk assessment data needs, identify the proper sources for various data, and to put in place the mechanisms for coordinated collection of consistent sets of data.

155 TITLE: PROCEDURE FOR EVALUATING TECH
SPECS (PETS)
CONTRACTOR: Brookhaven National Laboratory

	FY 85	FY 86	FY 87
BUDGET	500	800	700

OBJECTIVE:

Develop and demonstrate methodologies to utilize reliability and risk techniques in evaluating the scope, detailed requirements, and safety impact of plant technical specifications. The procedures developed are to provide a quantitative basis for making engineering judgements in revising the specifications and in responding to licensee submittals.

156 TITLE: OPERATIONAL SAFETY RELIABILITY RESEARCH
CONTRACTOR: Brookhaven National Laboratory

	FY 85	FY 86	FY 87
BUDGET	487	800	1000

OBJECTIVE:

This project is part of the planned resolution of Generic Issue II C 4, Reliability Engineering. This generic issue arises from the concern that during a plant's operating lifetime, the reliability of systems and activities important to safety might degrade from the designed-in reliability that was considered in the licensing process. This research is evaluating the effectiveness of a reliability program to prevent safety degradation during a plant's operating lifetime.

157 TITLE: INSPECTION GUIDANCE
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	533	200	1330

OBJECTIVE:

This program will review & evaluate existing PRA results, methods & data with the specific objective of developing information which will assist NRR licensing project managers resident inspectors, regional & headquarters staff to prioritize specific inspection activities on the basis of risk relevance, taking into account, wherever possible, the real-time status of the nuclear power plant.

158 TITLE: TRANSPORTATION MODAL STUDY
CONTRACTOR: Lawrence Livermore National Laboratory

	FY 85	FY 86	FY 87
BUDGET	260	220	0

OBJECTIVE:

Document the basis of protection provided by spent fuel casks designed to existing regulatory standards if these casks are subjected to severe transportation accident conditions.

159 TITLE: ACCIDENT SEQUENCE EVALUATION (PREV B6742)
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	1670	1200	700

OBJECTIVE:

Provide updated LWR accident sequence information for the NRC reference plants and extend the information for all operating and near-term operating plants to support NRC/IDCOR interface on severe accident technical issues, preparation of NUREG 1150, implementation of Severe Accident Policy Statement, NRC source term reassessment, and other safety and regulatory issues. Specifically, ASEP is to: 1) develop accident sequence likelihood information and insights for the reference plants; 2) extend the reference plant accident likelihood information to other LWRS including systems modeling, accident sequence likelihood characteristics and insights on major contributors; 3) catalog the dominant accident sequence information from existing PRAs into a single reference document.

160 TITLE: ACCIDENT SEQUENCE EVALUATION FY 85 FY 86 FY 87
CONTRACTOR: Idaho National BUDGET 570 540 700
Engineering Laboratory

OBJECTIVE:

Provides updated LWR accident sequence information for the NRC reference plan and extend the information for all operating and near-term operating plants to support NRC/IDCOR interface on severe accident technical issues, preparation of NUREG 1150, implementation of Severe Accident Policy Statement, NRC source term reassessment, and other safety and regulatory issues. Specifically, ASEP is to: 1) develop accident sequence likelihood information for the reference plants; 2) extend the reference plant accident likelihood information to other LWRS including systems modeling, accident sequence likelihood characteristics, and insights of major contributors; and 3) catalog the dominant accident sequence information from existing PRAs into a single reference document.

161 TITLE: REACTOR VITAL EQUIP FY 85 FY 86 FY 87
DETERMINATION TECHNIQUES BUDGET 250 450 0
CONTRACTOR: Los Alamos National Laboratory

OBJECTIVE:

To provide increased assurance that the reactor vital equipment assumptions and procedures used the NRC as a technical basis for safeguards reactor licensing decisions reflect current knowledge in the area of reactor safety and sabotage vulnerability. This project will also provide guidelines for implementation of the Vital Area Committee recommendations.

162 TITLE: STAT METHODS FOR NUCLEAR MC&A FY 85 FY 86 FY 87
CONTRACTOR: Pacific Northwest BUDGET 0193 50 0
Laboratories

OBJECTIVE:

To provide the NRC with a reference handbook needed to update and revise the regulatory guidance and the statistical methods for nuclear material control and accounting.

163 TITLE: REGULALTORY SUPPORT FY 85 FY 86 FY 87
CONTRACTOR: Pacific Northwest BUDGET 25 1100 2200
Laboratories

OBJECTIVE:

Support initiatives designed to improve regulations and to ensure that NRC regulatory decisions are based on adequate information. To accomplish these goals, efforts will be undertaken to develop, document, demonstrate, and implement new tools and methods for performing regulatory analyses. In addition, efforts will be directed toward the review and evaluation on a continuing basis of the existing regulatory requirements to determine their risk effectiveness; toward review of existing regulatory guides for possible revision or withdrawal; and in general exercising centralized control of ongoing rulemaking/standards activities.

164 TITLE: SYSTEMS RELIABILITY SERVICE STUDIES
CONTRACTOR: United Kingdom AEA

	FY 85	FY 86	FY 87
BUDGET	85	85	85

OBJECTIVE:

The objective of this agreement is to provide for collaboration between the parties in regard to the review and evaluation of USNRC program plans, methods, guidelines and standards relating to system analysis, risk assessment methodology and reliability data development. The UKAEA/SRS performs specific review and assessment tasks for the SIMRC relating to various topics including; probability and statistics for reliability analysis, accident sequence analysis, systems reliability analysis, reliability engineering and reliability assurance, and numberical risk criteria development.

165 TITLE: PROTECTIVE ACTION DECISIONMAKING
CONTRACTOR: Brookhaven National Laboratorty

	FY 85	FY 86	FY 87
BUDGET	250	350	100

OBJECTIVE:

To develop a revised protective action strategy for accidents at nuclear power plants based on results of new source term research.

166 TITLE: EVALUATION OF PROT ACTION RISKS
CONTRACTOR: Pennst

	FY 85	FY 86	FY 87
BUDGET	120	50	200

OBJECTIVE:

The purpose of this contract is, under radiological accident conditions, to determine how the non-radiological risks of evacuation compare with the radiological risks if no protective actions are taken.

167 TITLE: STATISTICAL TECHNIQUES FOR RISK ANAL
CONTRACTOR: Los Alamos National Laboratory

	FY 85	FY 86	FY 87
BUDGET	440	250	300

OBJECTIVE:

This program will provide a data base and improved methods for estimating component failure characteristics and consequently reducing the uncertainty in core melt frequency estimates. This program will also develop a data base for the Accident Sequence Evaluation Program, develop methods for quantifying common cause failures and continue direct support to RMIEP in the development of improved methods for PRA.

168 TITLE: ACCIDENT SEQUENCE PRECURSORS (PREV B6745)
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	435	325	0

OBJECTIVE:

Produce and validate a method to aid in systematically evaluating the significance of NPP operational experience LER data by estimating the likelihood of severe core damage, and show which precursor incidents or accidents contribute the most to this frequency estimate.

169 **TITLE:** CONSEQUENCE MODELING-NUC REAC ACCIDENTS
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	300	650	650

OBJECTIVE:

The objective of this work is to update the accident consequence models originally developed for the Reactor Safety Study in 1973, to account for new environmental transport, radiation dosimetry, health effect and economic models and data bases developed during the past decade, or more. Further, the code structure is being designed for ease of the user and to be readily amenable for uncertainty analyses. The latter is a major objective of the MELCOR program, which this FIN supports, in part.

170 **TITLE:** MELCORE
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	1250	1450	500

OBJECTIVE:

NRC is faced in the near term with determining how considerations of severe reactor accidents should be incorporated into the regulatory process and, further, on determining how the results of source term research should influence current regulatory requirements. Specific conversion decisions will be required in the areas of emergency planning, siting, and the implementation of a quantitative safety goal. The objective of this project is to develop, verify, and maintain a second generation accident simulation code for use in uncertainty analysis for probabilistic risk analysis.

171 **TITLE:** SEV. ACCIDENT RISK REBASELING AND REDUCTION PROGRAM (SARRP)
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	800	900	0

OBJECTIVE:

Provide risk profiles with associated uncertainties and assessments of the costs and risk reduction effectiveness of methods to prevent or mitigate the consequences of severe reactor accidents in six reference plants representing different containment types.

172 **TITLE:** ZION REBASELING
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	250	0

OBJECTIVE:

The objective is to provide a risk profile and an assessment of the values and impacts of the various prevention and mitigation features, for use in the staff report, NUREG-1150. Sandia National Laboratories (SNL) is performing the evaluation for five plants, and Zion, the sixth plant, will be done by BNL. SNL, however, will provide the "frontend" evaluation (the list of sequences) and containment event tree to BNL. Battelle Columbus Laboratories (BCL) will provide the source term calculations using the Source Term Code Package (STCP).

173 **TITLE: ANALYSIS OF VENTING OPTION**
CONTRACTOR: Idaho National Engineering Laboratory

	FY 85	FY 86	FY 87
BUDGET	387	450	0

OBJECTIVE:

Perform a systematic evaluation of venting a BWR, Mark I Containment, as a means of mitigating consequences of loss of containment so as to identify operator actions, procedures, or hardware which individually or collectively reduce risk.

174 **TITLE: RISK METHODOLOGY-OTHER MEDIA**
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	400	425	425

OBJECTIVE:

The risk methodology developed for NRC's quantitative assessment of isolation of HLW in bedded salt (under FIN A1192) needs to be extended to assist analysis of HLW isolation in basalt, tuff, domed salt, and granite. The objective of this project is to modify the risk methodology developed for the assessment of isolation of HLW bedded salt (under FIN A1192) so that the methodology will be applicable to analysing HLW isolation in basalt, tuff, domed salt, and granite.

175 **TITLE: COMPUTER CALCULATIONS IN SUPPORT OF THE HYDROCOIN STUDY**
CONTRACTOR: Sandia National Laboratory

	FY 85	FY 86	FY 87
BUDGET	75	100	100

OBJECTIVE:

To provide technical support for NRC participation in HYDROCOIN (an international cooperative investigation) will provide an international cross comparison of predictive models and codes which will provide insight into the appropriate use of such codes for NRC licensing evaluations. This research will enhance the confidence in the applicability of hydrologic programs for safety related calculations associated with geologic disposal of HLW and increase the NRC's awareness of the strength and limitations of various programs and modeling strategies that can or will be used to evaluate HLW geologic repository performance.

176 **TITLE: PITTING CORROSION**
CONTRACTOR: Brookhaven National Laboratory

	FY 85	FY 86	FY 87
BUDGET	150	150	200

OBJECTIVE:

To determine the degree of confidence in extrapolation of short-term laboratory tests of pitting corrosion rates to predictions over long times.

177 TITLE: VALENCE EFFECTS ON ADSORPTION FY 85 FY 86 FY 87
CONTRACTOR: Oak Ridge National BUDGET 150 150 150
Laboratory

OBJECTIVE:
Several of the most hazardous radionuclides in high-level waste can exist in multiple valence (a.k.a. oxidation) states. The valence state of the nuclide* in ground-water, and hence controls the mobility and sorption of the nuclide in a repository setting. The factors which control the valence state of nuclides in the earth are not well understood. This project has three primary objectives: 1) to identify and understand the factors which control radionuclide valence states under repository conditions; 2) to measure the solubility, speciation, and sorption properties of individual valence states of technetium (Tc), neptunium (Np), and uranium (U) under projected repository conditions; and 3) to assess laboratory methods of valence state control needed to replicate repository conditions in the laboratory. These data are needed to model the migration of radionuclides released from a repository, and to independently assess DOE calculations.

178 TITLE: SITE GEOCHEMISTRYN ADSORPTION FY 85 FY 86 FY 87
CONTRACTOR: Lawrence Berkeley BUDGET 687 500 600
Laboratory

OBJECTIVE:
This research will identify and gauge the relative importance of individaul hydrochemical processes controlling radionuclide behavior within and close to a geologic repository and form a basis for evaluating the chemical evolution of groundwater and transport of radionuclides.

179 TITLE: COUPLED INTERACTIONS- GEOTHERMAL FY 85 FY 86 FY 87
& HYDROTHERMAL SYSTEMS BUDGET 360 200 225
CONTRACTOR: Lawrence Berkeley Lab

OBJECTIVE:
The objective of this project is to identify, describe, and quantify coupled interactions which may be important to high-level waste isolation, by analogy with similar natural systems. Emplacement of high-level waste in a geologic repository will induce thermal, hydrologic, mechanical, and chemical changes in the geologic environment. Many such changes are coupled, i.e., the combined effects of the changes are different from the sum of the separate parts. Such coupled interactions are difficult to study in the laboratory because the geologic environment is very complex; because the effects often are very large-scale and cannot be scaled down to laboratory size; and because some effects operate over very long time periods. Natural analogues of high-level waste repositories, such as geothermal systems and hydrothermal ore deposits, can be used to observe the response of the geologic environment to coupled thermal, hydrologic, mechanical, and chemical changes at the scales of interest for repository licensing.

100 TITLE: LONG-TERM PERF OF HLW PACKAGING FY 85 FY 86 FY 87
MATLS BUDGET 1000 500 500
CONTRACTOR: Battelle Columbus Laboratories

OBJECTIVE:

NRC must assess the validity of DOE's demonstration that waste packages will meet the containment and controlled release requirements of 10 CFR Part 60. This project will identify the conditions and mechanisms of HLW package failure to be expected under repository conditions. The results will be used to support its claims of compliance with Part 60 requirements. This research will reduce the uncertainties associated with long term predictions of waste package corrosion rates and waste form dissolution under respository conditions.

101 TITLE: CONTAINER MANUFACTURING PARAMETERS FY 85 FY 86 FY 87
CONTRACTOR: Manufacturing BUDGET 90 100 0
Sciences Corp.

OBJECTIVE:

To assess the effect of manufacturing techniques and variabilities in these techniques on overpack performance.

102 TITLE: UNSAT FLOW & TRANS THRU FACT ROCK FY 85 FY 86 FY 87
PHASE II BUDGET 220 0 200
CONTRACTOR: University of Arizona

OBJECTIVE:

Assessment of techniques for modeling and data gathering and for describing unsaturated flow and transport in fractured rock. This study will provide the NRC licensing staff with an understanding and technical information for evaluating DOE's site characterization plans and studies on long-term predication of water (liquid/vapor movement) and contaminant transport through unsaturated fractured rock formations. The study will help to provide the NRC with a technical basis for developing regulations and licensing review procedures for assessing DOE submittals for HLW geologic repositories situated in the unsaturated zone. This research will reduce the uncertainties associated with estimation of parameters, such as recharge rate, used to model ground-water flow and transport in unsaturated fractured rock.

103 TITLE: THERMAL EFFECTS ON REPOSITORY ROCKS FY 85 FY 86 FY 87
CONTRACTOR: University of Delaware BUDGET 100 100 100

OBJECTIVE:

The objective of this project is to use scale model laboratory tests to evaluate current conceptual and mathematical models of heat transfer from individual HLW packages and from the aggregate of emplaced HLW which can not be tested over long times.

104 TITLE: PITTING STATISTICS FY 85 FY 86 FY 87
CONTRACTOR: National Bureau of BUDGET 210 150 200
Standards

OBJECTIVE:

To assess the ranges of repository environmental condition that control initiation and rates of pitting corrosion in overpack materials.

		FY 85	FY 86	FY 87
185 TITLE: GROUNDWATER & TRANSPORT OF CONTAMINANTS CONTRACTOR: ISI	BUDGET	227	155	425

OBJECTIVE:
The objective of this project is to provide NRC with an independent technical base to judge whether DOE's models and measurement methods for describing the hydrology of a repository site in low permeability saturated fractured rock are appropriate to such media.

		FY 85	FY 86	FY 87
186 TITLE: PROP OF DECON WASTES CONTRACTOR: Brookhaven National Laboratory	BUDGET	100	150	150

OBJECTIVE:
To determine the leaching characteristics of solidified decontamination waste in expected disposal environments.

		FY 85	FY 86	FY 87
187 TITLE: LLW SOURCE TERM CONTRACTOR: Brookhaven National Laboratory	BUDGET	200	400	500

OBJECTIVE:
In order to assess compliance with Part 61 requirements for modeling performance of LLW disposal the NRC needs a comprehensive set of "source terms". This research will develop a set of "source terms" related to the amount of radionuclides in waste packages and the rate at which they are released from the packages and enter the soils at the disposal site. These will be used for radionuclide transport modeling of LLW disposal sites during licensing reviews. This research will reduce the uncertainties associated with the chemical form and quantity of radionuclides released from shallow land burial facilities, such as C-14, Co-60, and Cs-137.

		FY 85	FY 86	FY 87
188 TITLE: CHAR OF LL RAD DECON WASTE CONTRACTOR: Idaho National Engineering Laboratory	BUDGET	100	100	100

OBJECTIVE:
The characteristics of LLW waste from the decontamination of reactor systems must be known in order to establish site performance by modeling the migration of radionuclides for LLW disposal sites. This project will provide reachability data by studying actual wastes from LWR decontamination. The results will be used in establishing the LLW source term for decontamination wastes for use in NRC licensing evaluations. This research will reduce the uncertainties in calculations of the species, quantities, and mobilities of radionuclides from decontamination wastes, such as Ni-63 and Co-60, important to safety of LLW disposal.

		FY 85	FY 86	FY 87
189 TITLE: SFTY ASSESSMENT OF ALT TO SHALLOW LAND BURIAL CONTRACTOR: Idaho National Engineering Lab	BUDGET	130	150	0

OBJECTIVE:
This project will help identify safety issues for engineered enhancements or alternatives to shallow land burial for disposal of low level waste.

190 TITLE: CHEMICAL SPECIES OF MIGRATING RADIONUCLIDES
CONTRACTOR: Pacific Northwest Laboratories

	FY 85	FY 86	FY 87
BUDGET	150	100	0

OBJECTIVE:

10 CFR Part 61 requires a performance assessment of LLW disposal. This research is a beginning assessment of the effectiveness and practicability of existing models, codes, and data gathering techniques which may be used in predicting LLW site performance.

191 TITLE: SOIL-BIOTICH-HYDRO PROCESSESG
CONTRACTOR: Pacific Northwest Lab

	FY 85	FY 86	FY 87
BUDGET	95	100	0

OBJECTIVE:

Chemicals from plant roots have been observed to affect the mobility of radionuclides in soils. This work will produce an integrated understanding of soil-plant-hydrologic processes governing the mobility and biological availability of radionuclides from LLW disposal facilities.

192 TITLE: LLW/SLB MODEL FIELD VALIDATION
CONTRACTOR: Pacific Northwest Lab

	FY 85	FY 86	FY 87
BUDGET	92	172	400

OBJECTIVE:

Geostatistical methods for describing hydrologic processes and parameters in unsaturated heterogeneous soils have not been field validated. This research will test the validity and applicability of such techniques to HLW and LLW disposal performance assessments. The results will assist the licensing staff to identify and quantify the uncertainties using statistical methods for the prediction of radionuclide transport form HLW repositories and LLW disposal facilities. Uncertainties associated with spatial variability in moisture content, hydraulic conductivity, and dispersivity will be quantified.

193 TITLE: STOCHASTIC HYDROGEOLOGIC ANALYSIS
CONTRACTOR: Mass Institute of Technology

	FY 85	FY 86	FY 87
BUDGET	120	50	0

OBJECTIVE:

Before the techniques of stochastic hydrology can be used in reviewing license applications for LLW disposal, the applicability of these techniques for this purpose needs to be assessed. This research will provide a theoretical base for evaluating LLW site characterization plans using statistical methods of predicting ground-water flow and solute transport in unsaturated heterogenous earth materials. This research will reduce the present level of uncertainty in modeling movement of radionuclides in heterogeneous unconsolidated soils.

194 TITLE: ASSESSMENT OF CLOSURE METHODS
CONTRACTOR: UCA-Lab Bio Envir Science

	FY 85	FY 86	FY 87
BUDGET	175	175	200

OBJECTIVE:

Experience with shallow land burial of LLW at sites in humid areas indicates that water infiltration through trench caps is a problem. This research will assess the effectiveness of a number of methods under consideration by the States and industry to control water entry through LLW site covers in humid areas.

195 TITLE: INSTRUMENTATION FOR KENTUCKY NETWORK
CONTRACTOR: Univ. Of Kentucky

	FY 85	FY 86	FY 87
BUDGET	20	7	0

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded on Kentucky. This data includes earthquake locations, magnitudes, source parameter, phase arrival time,etc.

196 TITLE: GILES COUNTY SEISMIC PROFILING
CONTRACTOR: Virginia Polytech Institute

	FY 85	FY 86	FY 87
BUDGET	25	25	0

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological reflection data generated near the Giles County Seismic Zone. Both P-wave and S-wave reflection profiles are being acquired to define subsurvace structure. The data also include earthquake locations, magnitudes, source parameter, phase arrival time, etc. A comparison of the two sets of data is expected to provide insights into the causes of the seismicity in Giles County.

197 TITLE: DOWNHOLE STRONG MOTION STUDIES
CONTRACTOR: University of California

	FY 85	FY 86	FY 87
BUDGET	70	103	75

OBJECTIVE:

There is presently no acceptable method for determining the attenuation of seismic shear and body waves in soil. This experiment is designed to measure this attenuation by the use of down-hole seismometers and surface seismometers in a seismically active area of California.

198 TITLE: GEO & SEISMO SITING STUDIES
CONTRACTOR: U.S. Geological Survey

	FY 85	FY 86	FY 87
BUDGET	290	1000	870

OBJECTIVE:

The objective of this work is to provide NRR with the data and analytical techniques necessary to maintain an independent technical basis for the review of applications.

A. Lack of basic seismological data from any other source for the Charleston region.
B. The interpretation of high acceleration ground motion at short distances.
C. The interpretation of the propagation of strong ground motion with distance.
D. The implications of the numerous theories on the cause of eastern earthquakes.

199 TITLE: SOUTHERN NEW MADRID NETWORK
CONTRACTOR: Memphis State Unversity

	FY 85	FY 86	FY 87
BUDGET	100	93	120

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded near the southern end of the New Madrid Seismic Zone. This data includes earthquake locations, magnitudes, sources parameter, phase arrival time, etc.

200 TITLE: SOIL SETTLEMENT
CONTRACTOR: Corp of Engineers/ Waterways Experimental Station

	FY 85	FY 86	FY 87
BUDGET	0	100	250

OBJECTIVE:

The latest position of the United States Geological Survey (USGS) on the 1886 Charleston earthquake could result in the postulation of ground motions higher than the Safe Shutdown Earthquake (SSE) at many nuclear power plant sites in the Eastern United States. Since many of these plants are founded on soil, the stability of nuclear power plant structures, systems and components subject to possible foundation soil liquefaction and dynamic settlement becomes a matter of concern. The objective of this research is the validation of dynamic analyses models capable of predicting settlements resulting from soil liquefaction.

201 TITLE: NEW MADRID RESEARCH PROGRAM
CONTRACTOR: St. Louis University

	FY 85	FY 86	FY 87
BUDGET	113	120	120

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded near the southern end of the New Madrid Seismic Zone. This data includes earthquake locations, magnitudes, source parameter, phase arrival time, etc.

202 TITLE: OHIO/INDIANA SEISMIC NETWORK
CONTRACTOR: Univ. of Michigan

	FY 85	FY 86	FY 87
BUDGET	113	120	120

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded in Ohio and Indiana. This data includes earthquake locations, magnitudes, source parameter, phase arrival time, etc.

203 TITLE: NEOTECTONIC INVESTIGATIONS		FY 85	FY 86	FY 87
CONTRACTOR: Univ. of South Carolina	BUDGET	100	100	100

OBJECTIVE:

The tectonic cause of seismicity in the Southeastern United States is not well understood. The seismic history there includes the large 1886 Charleston earthquake. The combination of that event and the unknown tectonics results in a high uncertainty in seismic hazard assessments. Under this project, and evaluation of several hypotheses on the cause of seismicity in the Southeastern uncertainty in seismic hazard assessment of NPP's.

204 TITLE: CHARLESTON EARTHQUAKE PROJ		FY 85	FY 86	FY 87
CONTRACTOR: Law Engineering	BUDGET	317	250	200

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing geophysical and geological data from the vicinity of Charleston, South Carolina, which will better define the possible mechanism and structures associated with the Charleston earthquake. The geophysical data, including seismic reflection profiles, will define the subsurface at the depths of earthquake hypocenters. The results of this work will narrow down the range of theories that can explain the Charleston earthquake and serve to better define the seismicity of the eastern seaboard.

205 TITLE: IN SITU STRESS MEASUREMENTS		FY 85	FY 86	FY 87
CONTRACTOR: Engrs. International	BUDGET	120	150	0

OBJECTIVE:

The cause of seismicity in the Northeastern United States is not well understood. The objectives of this project are to determine the in situ stresses and the direction of the faulting occurring in the seismic zones. The seismic networks in the New England States, the Southeastern States, the New Madrid area and the Nemaha Ridge area have identified active seismic zones; however, they have not fully identified the direction of faulting. This information is needed for testing hypotheses on the causes of seismicity. Better understanding of the causes of seismicity will result in reduced uncertainty in the relationship between seismic hazards, seismicity and active geologic structures.

206 TITLE: EQUAKE RESISTANT DESIGN CRITERIA FY 85 FY 86 FY 87
CONTRACTOR: Struct & Erthqk Engr Con BUDGET 150 40 150

OBJECTIVE:
There is paucity of recorded strong ground motion data for the Eastern United States. Currently, records from other geographic areas must be used. If records were available, it would be possible to significantly reduce the uncertainty associated with defining the design response spectrum. The objective of this research is to develop analytical techniques that could be used to generate useable design response spectra for nuclear power plant sites for which a comprehensive suite of strong motion records are not available. The results will be used by NRR in the review of plant license applications and amendments.

207 TITLE: TECH BASIS SEISMIC STANDARDS FY 85 FY 86 FY 87
CONTRACTOR: Request for Proposal BUDGET 0 50 100

OBJECTIVE:
Objective is to provide prompt basic earth science information for use in NRC investigations prompted by current significant seismic events or geologic discoveries; e.g., the January 9, 1982, New Brunswick earthquake and its aftershocks, and the recently identified Meers fault in Oklahoma.

208 TITLE: CANADIAN SEISMIC COOP AGREEMENT FY 85 FY 86 FY 87
CONTRACTOR: Canadian Comm Corp. BUDGET 305 165 165

OBJECTIVE:
The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded in the vicinity of the US/Canada border. This data includes earthquake locations, magnitudes, source parameter, phase arrival time.

209 TITLE: NE US SEISMOGRAPHIC NETWORKS FY 85 FY 86 FY 87
CONTRACTOR: Columbia University BUDGET 250 330 270

OBJECTIVE:
The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded in New York State. This data includes earthquake locations, magnitudes, source parameter, phase arrival time, etc.

210 TITLE: REMOTE SENSING OBS OF NE NEOTECTONICS
CONTRACTOR: PENNST

	FY 85	FY 86	FY 87
BUDGET	173	120	100

OBJECTIVE:

The tectonic cause of seismicity in the Northeastern United States is not well understood because this is a structurally complex region where geologic structures are obscured by vegetation, where there are few deep boreholes to give subsurface information, and where damaging earthquakes occur at infrequent intervals. Therefore, there is great uncertainty in estimating seismic hazards for the region. This project will test hypotheses on the causes of seismicity in areas within the Northeastern U.S. where there is localized seismic activity. This will be done through the use of remote sensing coupled with ground investigations to assess the cause of seismicity. Better understanding of the cause of seismicity will reduce uncertainty in the relationship between seismic hazard and seismically active geologic structures.

211 TITLE: BROAD-BAND INSTRUMENTATION
CONTRACTOR: RONDOUT, Associates

	FY 85	FY 86	FY 87
BUDGET	51	0	50

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is providing wide dynamic-range, broad-band data on seismic events in the Northeast and on the propagation characteristic there. This data include earthquake locations, mangitudes, source parameters, phase arrival times, etc.

212 TITLE: PIEDMONT SEISMIC REFLECTION
CONTRACTOR: Virginia Polytech Institute

	FY 85	FY 86	FY 87
BUDGET	230	250	200

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is heeded to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing seismic reflection data generated in the Southeast. Data may include magnetic and gravity maps and other geological and geophysical data providing information on crustal structure at the depths of earthquake hypocenters.

213 TITLE: REGIONAL SEISMOGRAPHIC NETWORK
CONTRACTOR: Memphis State University

	FY 85	FY 86	FY 87
BUDGET	120	160	130

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project seismological data recorded in Tennessee and North Carolina. This data includes earthquake locations, magnitudes, source parameter, phase arrival time, etc.

214 TITLE: VA-REGIONAL SEISMOGRAPHIC NETWORK
CONTRACTOR: Virginia Polytech Institute

	FY 85	FY 86	FY 87
BUDGET	160	200	150

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded in Tennessee and West Virginia. This data includes earthquake locations, magnitudes, source parameter, phase arrival time, etc.

215 TITLE: GA-AL-REGIONAL SEISMOGRAPHIC NETWORK
CONTRACTOR: Georgia Institute of Tech

	FY 85	FY 86	FY 87
BUDGET	100	120	100

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded in Georgia and Alabama. This data includes earthquake locations, magnitudes, source parameter, phase arrival time, etc.

216 TITLE: NEW ENGLAND SEISMOGRAPHIC NETWORK
CONTRACTOR: Boston College

	FY 85	FY 86	FY 87
BUDGET	309	300	270

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded in New England. This data includes earthquake locations, magnitudes, source parameter, phase arrival time, etc.

217 TITLE: MASS./NEW HAMPSHIRE SEISMOGRAPHIC NETWORK
CONTRACTOR: Mass Institute of Technology

	FY 85	FY 86	FY 87
BUDGET	135	120	130

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded in Massachusetts and New Hampshire. This data includes earthquake locations, magnitudes, source parameter, phase arrival time, etc.

218 TITLE: PENNSYLVANIA SEISMOGRAPHIC NETWORK
CONTRACTOR: PENNST

	FY 85	FY 86	FY 87
BUDGET	110	95	110

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded in Pennsylvania and Maryland. This data includes earthquake locations, magnitudes, source parameter, phase arrival time, etc.

219 TITLE: LONG ISLAND SEISMIC ARRAY
CONTRACTOR: SUNY

	FY 85	FY 86	FY 87
BUDGET	81	45	50

OBJECTIVE:

The tectonic cause of seismicity in the Eastern United States is not well understood. Additional data is needed to assist the NRC in conducting regulatory reviews and establishing appropriate regulations and policies. This project is part of a program to obtain such data. This project is providing basic seismological data recorded on Long Island. This data includes earthquake locations, magnitudes, source parameter, phase arrival time, etc.

220 TITLE: COMMITTEE ON SEISMOLOGY
CONTRACTOR: NAS

	FY 85	FY 86	FY 87
BUDGET	20	20	20

OBJECTIVE:

The Committee on Seismology is a standing committee of the National Academy of Science composed of leading seismologists from industry, academia and government. The results of their efforts are advise the federal government in the area of seismology. The results of this work of the committee will be used to help determine if the NRC policies, guidance and research programs concerning seismic hazard are properly directed. This is a grant to the National Academy of Sciences to partially offset the cost of gathering these expert panels together and for the publication of their findings in special reports.

221 TITLE: WORKSHOP ON STRONG GROUND MOTION
CONTRACTOR: Earthquake Engr Research Institute

	FY 85	FY 86	FY 87
BUDGET	0	20	0

OBJECTIVE:

There are gaps in the understanding of the generation and propagation of strong ground motion resulting from seismic events in the Eastern U.S. The Earthquake Engineering Research Institute (EERI) is sponsoring the Third National Conference on Earthquake Engineering to bring together earthquake engineers and scientists to exchange ideas and theories. This conference will include a workshop that is intended to help reduce the uncertainty in seismic hazard assessment that results from these gaps. This workshop will help to reduce the uncertainties in the NRC's independent evaluations of licensee submittals.

222 TITLE: CRUSTAL SUBSIDENCE MAINE
CONTRACTOR: Main Geological Survey

BUDGET	FY 85	FY 86	FY 87
	75	75	0

OBJECTIVE:

The cause of seismicity in Eastern United States is not well understood. Along coastal Maine there is an area that for the last 500-1000 years has been experiencing very rapid crustal subsidence. That is associated with seismicity. This investigation is directed at determining the cause of the subsidence and the seismicity associated with it. Better understanding of the cause of the seismicity will help reduce uncertainty in seismic hazard assessment for NPP's located in the Eastern U.S.

223 TITLE: GEOLOGICAL SCIENCES BOARD
CONTRACTOR: NAS

BUDGET	FY 85	FY 86	FY 87
	10	10	10

OBJECTIVE:

The Geological Sciences Board is a standing Board of the National Academy of Sciences composed of leading geoscientists from industry, academia, and government. The purpose of their efforts is to advise the Federal government in the area of the geological sciences. The results of the board will be used to help determine if the NRC policies, guidance, and research programs concerning geological hazards are properly directed. This grant to the National Academy of Sciences is to partially offset the cost of gathering these expert panels together and of publishing their findings in special reports.

224 TITLE: ACUTE MORBIDITY & MORTALITY IN ANIMALS
CONTRACTOR: Inhalation Toxicology

BUDGET	FY 85	FY 86	FY 87
	260	250	0

OBJECTIVE:

To develop information that will improve the estimates of potential early health effects of postulated accidents and sabotage in nuclear power plants, fuel cycle facilities, and transportation. The specific objective is to provide experimental data necessary to verify the early mortality model and to develop models for morbidity and mortality expected to occur within 18 months after exposure to radionuclides.

225 TITLE: METABOLIC STUDIES OF INHALED YELLOWCAKE IN ANIMALS
CONTRACTOR: Inhalation Toxicology

BUDGET	FY 85	FY 86	FY 87
	140	100	200

OBJECTIVE:

The results will be used to determine lung deposition and organ transfer factors, and to examine kidney toxicity of yellowcake inhalation.

226 TITLE: METABOLISM STUDY OF THORIUM WORKERS
CONTRACTOR: Argonne National Laboratory

	FY 85	FY 86	FY 87
BUDGET	150	130	200

OBJECTIVE:

The objective of this research is to enhance the human data base on the behavior and health effects of thorium and other alpha emiting radionuclides.

227 TITLE: GASTROINTESTINAL ABSORPTION OF PU AND ACTINIDES
CONTRACTOR: Argonne National Laboratory

	FY 85	FY 86	FY 87
BUDGET	91	105	250

OBJECTIVE:

The current objectives are (1) to determine the gastrointestinal absorption of actinides in a nonhuman primate species, the baboon, to provide a more reliable basis for the extrapolation of GI absorption data in experimental animals to humans, and (2) to determine the steady-state amount of uranium in human bone for a population of persons with prolonged (25 y) and known daily intakes of uranium in drinking water.

228 TITLE: QUALITY FACTORS OF LOW DOSE NEUTRONS
CONTRACTOR: Argonne National Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	259	0

OBJECTIVE:

To determine the relative biological effectiveness of fission neutrons at occupational exposure levels.

229 TITLE: LUNG CANCER IN WOMEN - RADON
CONTRACTOR: Argonne National Laboratory

	FY 85	FY 86	FY 87
BUDGET	0	16	0

OBJECTIVE:

Determine whether the Lung Cancer risk observed in exposed women is, after adjustment for smoking habits of the study population, consistent with lung cancer risks observed in radon exposed miner populations. Present risk estimates for radon are based entirely on miner populations. Thus, the results of this study are valuable in assessing the generality of these estimates.

230 TITLE: REFERENCE MAN-UPDATE
CONTRACTOR: Oak Ridge National Laboratory

	FY 85	FY 86	FY 87
BUDGET	25	30	50

OBJECTIVE:

This research will update anatomical and physiological information for adult males and extend the data base to adult females and children of both sexes.

231 TITLE: EARLY EFFECTS OF INHALED RADIONUCLIDES IN ANIMALS
CONTRACTOR: Pacific Northwest Laboratories

	FY 85	FY 86	FY 87
BUDGET	280	200	0

OBJECTIVE:

To develop information that will improve the estimates of potential early health effects of postulated accidents and sabotage in nuclear power plants, fuel cycle facilities and transportation. The specific objective is to provide experimental data necessary to verify the early mortality model and to develop models for morbidity and mortality expected to occur within 18 months after exposure to radionuclides.

232 TITLE: METABOLISM OF SR PU AND AM IN MONKEYS
CONTRACTOR: Lawrence Berkeley Lab

	FY 85	FY 86	FY 87
BUDGET	130	140	0

OBJECTIVE:

The results will be used to determine organ uptake and retention factors following injection of strontium, plutonium, and americium.

233 TITLE: SUPPORT FOR NAS COMMITTEE BEIR IV
CONTRACTOR: Environmental Protection Agency

	FY 85	FY 86	FY 87
BUDGET	130	150	200

OBJECTIVE:

To develop state-of-the-art methods for quantitative assessment of risk to humans from internally deposited alpha-emitting radionuclides and their decay products (IDAER).

234 TITLE: RADIATION PROTECTION/MEASUREMENT STUDY
CONTRACTOR: National Council Rad. Prot. & Meas.

	FY 85	FY 86	FY 87
BUDGET	75	200	0

OBJECTIVE:

NCRP is an organization of scientists and physicians expert in radiation related sciences and medicine, which by Congressional Charter provides the nation advice on radiation protection. The results of their efforts are published and serve as a base for Federal, State, and local agencies to develop sound protection practices, including the use of radiation in the healing arts.

235 TITLE: DEVELOP RAD PROT. STANDARDS
CONTRACTOR: Int'l Comm. Radiation Protection.

	FY 85	FY 86	FY 87
BUDGET	10	10	25

OBJECTIVE:

ICRP is an international organization of scientists expert in radiation physics, biology, and medicine that provides recommendations on radiation protection practices. All international standards are based on these recommendations.

236 TITLE: SURVEILLANCE; IND/DOE RES & NPP ALARA PGMS
CONTRACTOR: Brookhaven National Laboratory

	FY 85	FY 86	FY 87
BUDGET	120	245	0

OBJECTIVE:

Objective is to establish affective surveillance of industry R & D projects on dose reduction aid ALARA engineering by developing work relationship's with national & international government & industry groups, maintaining comprehensive data base on information obtained, analyse projects for effectiveness and developing methods for informing government and industry management of important new dose reduction efforts.

237 TITLE: INTERNAL DOSE CALCULATIONS ASSISTANCE
CONTRACTOR: Oak Ridge National Lab.

	FY 85	FY 86	FY 87
BUDGET	15	20	0

OBJECTIVE:

The problem is that frequent requests are made of NRC staff to provide approved methods of estimating intakes and internal doses from bioassay data. The goal of this project is to provide NRC staff access to state-of-the-art techniques for calculating worker internal dose, body burdens, and excretion rates. Oak Ridge National Lab (ORNL) monitors major research and development projects being performed by DOE, NIH, and others, and extracts important findings for inclusion into the highly advanced ORNL data banks and computer programs. This technical support is then available to ORPB/RES staff to assit them in reviewing regulatory requirements, such as the proposed Part 20 revisions, in developing licensee guidance on bioassay and respiratory protection, and in providing up-to-date technical information to other NRC offices, other governmental agencies, licensees and groups such as INPO, EPRI, and EEI.

238 TITLE: RAD EXP INFO RPT SYS
CONTRACTOR: Oak Ridge National Lab.

	FY 85	FY 86	FY 87
BUDGET	202	205	200

OBJECTIVE:

To provide computer, programming and processing support for the operation of REIRS.

239 TITLE: TESTING EXTREMITY DOSIMETRY STANDARDS FY 85 FY 86 FY 87
CONTRACTOR: Pacific Northwest BUDGET 0 100 0
Laboratories

OBJECTIVE:

NRC inspectors regularly observe inadequate dosimetry for monitoring the heads and extremities of workers who perform tasks in non-uniform radiation fields. In order to improve this situation the NRC staff plans to recommend that licensees be required to use only extremity dosimeters and processors that have passed performance tests as defined in an ANSI standard being developed by the Health Physics Society. The contractor is to determine if the draft standard (P/N13.32, "Standard for the Performance Testing of Extremity Dosimeter") is appropriate for testing the performance of extremity dosimeter processors, or to make recommendations to the HPS regarding changes necessary to ensure that the standard is neither too straight nor too lenient.

Appendix C

Planned FY 1986 Nuclear Research and Development Program of the U.S. Department of Energy

DOE CONTRACTS LIST

FY 1986

LWR Safety & Technology

1. TITLE: ADVANCED REACTOR ASSESSMENT
   CONTRACTOR: Idaho National Engineering Laboratory

   FY 86 BUDGET: 1,000*

   SCOPE: Development of severe accident licensing methodology for advanced LWRs.

2. TITLE: EXTENDED BURNUP OF LWR FUEL
   CONTRACTOR: Several utility and fuel supplier contractors

   FY 86 BUDGET: 2,799

   SCOPE: Development of advanced fuel designs possessing greater longevity, better economics, improved integrity, and reduced spent fuel waste generation.

3. TITLE: LOFT
   CONTRACTOR: Idaho National Engineering Laboratory

   FY 86 BUDGET: 9,225

   SCOPE: Cleanup of LOFT facility.

4. TITLE: SOURCE TERM
   CONTRACTOR: Hanford Engineering Development Laboratory

   FY 86 BUDGET: 400

   SCOPE: Aerosol behavior in reactor containments.

5. TITLE: PLANT LIFE EXTENSION
   CONTRACTOR: Sandia National Laboratory

   FY 86 BUDGET: 495

   SCOPE: Removal of technical and institutional barriers to longer life and license of nuclear plant.

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* All dollar amounts in thousands

6. TITLE: TECHNOLOGY MANAGEMENT CENTER
CONTRACTOR: Sandia National Laboratory

FY 86 BUDGET: 250

SCOPE: Management and planning of overall technology transfer activities in LWR area.

7. TITLE: ALWR ASSISTANCE
CONTRACTOR: Sandia National Laboratory

FY 86 BUDGET: 10

SCOPE: Technical review and assistance in ALWR program.

8. TITLE: PLANT AVAILABILITY
CONTRACTOR: Argonne National Laboratory

FY 86 BUDGET: 250

SCOPE: Analysis of regulatory-imposed outages in the United States versus the Federal Republic of Germany.

9. TITLE: STEP
CONTRACTOR: Argonne National Laboratory

FY 86 BUDGET: 100

SCOPE: Post-test examination of the Source Term Experiment Program (STEP) tests.

10. TITLE: LOFT
CONTRACTOR: Idaho National Engineering Laboratory

FY 86 BUDGET: 275

SCOPE: Post-irradiation examination of final LOFT test fuel.

11. TITLE: TMI
CONTRACTOR: Idaho National Engineering Laboratory

FY 86 BUDGET: 30,736

SCOPE: Development of technology to recover from severe accident; R&D program to obtain information to improve nuclear reactor safety and regulation.

12. TITLE: ADVANCED LWR
CONTRACTOR: Six industrial contractors

FY 86 BUDGET: 4,510

SCOPE: 15 tasks in support of EPRI Advanced LWR Program, covering small plant designs, large plant design verification, constructibility, and advanced I&C.

13. TITLE: ADVANCED LWR
CONTRACTOR: Oak Ridge National Laboratory

FY 86 BUDGET: 150

SCOPE: Review of advanced reactor designs and criteria.

Regulatory Development

14. TITLE: RISK-BASED LICENSING
CONTRACTOR: Sandia National Laboratory

FY 86 BUDGET: 200

SCOPE: Risk-based review of licensing to help reform regulatory process.

Plant Performance

15. TITLE: INTERNATIONAL NUCLEAR POLICY AND PROGRAM
CONTRACTOR: Argonne National Laboratory

FY 86 BUDGET: 40

SCOPE: Support services to several bilateral cooperative arrangements.

16. **TITLE:** NUCLEAR/FOSSIL POWER PLANT ECONOMICS, COSTS
CONTRACTOR: Oak Ridge National Laboratory

FY 86 BUDGET: 720

SCOPE: Economic analysis, cost estimating methods, and updating of Energy Economic Data Base.

17. **TITLE:** ECONOMIC REGULATION
CONTRACTOR: Oak Ridge National Laboratory

FY 86 BUDGET: 200

SCOPE: Issues in economic regulation such as management practices, financial arrangements, accounting practices, capital recovery methods, prudency and institutional considerations.

18. **TITLE:** INSTITUTIONAL ISSUES
CONTRACTOR: Oak Ridge National Laboratory

FY 86 BUDGET: 200

SCOPE: Institutional, financial, and regulatory issues including impact of future nuclear plants on national economics, choice of base-load generation options, energy security, and U.S. nuclear supply infrastructure.

19. **TITLE:** CONSTRUCTIBILITY
CONTRACTOR: Oak Ridge National Laboratory

FY 86 BUDGET: 300

SCOPE: Institutional, financial, and regulatory issues including issues of nuclear plant constructibility and availability and operating and maintenance costs.

Advanced Converter Development

20. TITLE: HIGH TEMPERATURE GAS REACTOR PROGRAM - FUELS & MATERIALS TESTING, DESIGN & LICENSING

CONTRACTORS:
GA Technologies (15,227)
Oak Ridge National Laboratory (3,450)
General Electric Co. (2,915)
Bechtel (2,235)
Stone & Webster (2,235)
Combustion Engineering (1,835)
Gas Cooled Reactor Associates (423)
Idaho National Engineering Laboratory (380)

FY 86 BUDGET: 20,700

SCOPE: Design and licensing activities, fuels and materials R&D/testing, and design code development.

21. TITLE: LIQUID METAL REACTOR - ADVANCED CONCEPTS DEVELOPMENT

CONTRACTORS:
General Electric Co. (8,073)
Rockwell International (5,731)
Westinghouse (965)
Oak Ridge (400)
HEDL (375)
Pacific Northwest Lab (231)
Argonne National Lab (200)
Los Alamos (104)
ETEC (104)
Idaho National Engineering Lab (104)
Bechtel (151)
Brown & Root (115)
Sandia National Lab (34)

FY 86 BUDGET:
SAFR design, safety & licensing (5277)
PRISM design, safety & licensing (8650)
Long Life Core System Assessments (192)
Licensing Interactions/Cost Reduction (935)
Small Plants Applications Assessments (100)
Evaluation & Assessments of PRISM & SAFR (1645)
Support DOE-PNC Criticality Data Program (231)
CRBRP/Monju Exchange & Provide Site Rep in Japan (597)

Total Budget: 17,627

SCOPE: Design activities, safety and licensing analyses, and evaluations and assessments of PRISM and SAFR concepts.

22. **TITLE:** LIQUID METAL REACTOR - POWER CONVERSION TECHNOLOGY DEVELOPMENT

CONTRACTORS:

Rockwell International	(900)
Oak Ridge National Lab	(750)
ETEC	(540)
Argonne National Lab	(330)
HEDL	(330)
General Electric	(260)
Pacific Northwest Labs	(235)
Westinghouse	(235)

FY 86 BUDGET:

Visual Inspection Technology for Objects in Sodium	(330)
Demonstrate High Temperature Design Methods	(385)
Shrouded Inducer Pool Pump Testing	(845)
PRISM Rotating Plud Design & Testing	(106)
RV Air Cooling Inspection Systems Design & Test	(270)
PRISM Control Rod Driveline Bellows Testing	(30)
PRISM & SAFR Component Design & Analyses	(330)
Nondestructive Testing of SG Tubes	(106)
Materials Test - LMR Stainless Steel Applications	(40)
IHX Hydraulic Model Design & Fabricate	(135)
Design, Fabricate & Test High Temp Flux Monitor	(211)
EM Pump Testing	(160)
Support DOE - PNC Criticality Data Program	(235)
Control Rod Drive Testing	(100)
Guard Vessel Stability Testing	(134)
Codes & Standards & QA Applications Assessment	(77)
Artificial Intelligence - Plant Operators Assist	(150)
Total Budget:	3,660

SCOPE: Testing of shrouded inducer pool pump; design, fabrication, and testing of high temperature flux monitor; sodium visual inspection R&D; PRISM/SAFR component design and analyses; demonstrate high temperature design methods.

23. **TITLE:** LIQUID METAL REACTOR - NUCLEAR SYSTEMS TECHNOLOGY DEVELOPMENT

CONTRACTORS:

Contractor	Amount
Argonne National Lab	(3725)
Oak Ridge National Lab	(2388)
General Electric	(1123)
HEDL	(764)
ETEC	(573)
Pacific Northwest Labs	(477)
Rockwell International	(286)
Babcock & Wilcox	(191)
Westinghouse	(95)

FY 86 BUDGET:

Item	Amount
SAFR/PRISM/LSPB Shielding Designs & Analyses	(289)
RVACS/RACS Model Test & Analyses	(144)
RVACS Full Scale Testing	(241)
RVACS Emissivity Tests & Specs Preparation	(34)
RISKSP Computer Code Verification	(161)
PRISM/SAFR Core Design Analyses & Studies	(1738)
U-Pu-Zr Metallic Fuel System Qualification	(388)
Innovative Design Core Key Feature Tests	(1644)
Impact of Smaller Fuel Pins on SAFR Core Design	(95)
GSCRAP Seismic Code Validation	(48)
DOE-PNC Jasper Shielding Evaluations	(483)
Small Scaled DRACS Testing	(429)
Decay Heat Removal Model Testing	(286)
Support DOE-PNC Criticality Data Program	(477)
DOE-PNC Reliability Data Collection	(231)
Seismic Modeling for Advanced Concepts	(351)
PRISM Core Design	(447)
Core Designs-Multimodular Control System	(1672)
Actinide Measurements (US/UK Agreement)	(96)
Qualify Neutron Absorber Assemblies for LMRs	(384)

Total Budget: 9,622

SCOPE: PRISM/SAFR Core design analyses; code designs-multimodular control system; innovative design core key features tests; Jasper shielding evaluations; criticality data development; small scale DRACS testing; seismic modeling for advanced concepts; neutron absorber assemblies qualification.

24. TITLE: CIVILIAN REACTOR DEVELOPMENT SUPPORT - REACTOR DEVELOPMENT SUPPORT - POOL PLANT DESIGN AND EVALUATION/EPRI

CONTRACTORS: Rockwell International (858)
General Electric (643)
Westinghouse (421)
Bechtel (349)
Brown & Root (161)
GA Technologies (94)

FY 86 BUDGET: 2526

SCOPE: Large pool plant design activities.

25. TITLE: CIVILIAN REACTOR DEVELOPMENT SUPPORT - SAFEGUARDS AND PROGRAM ASSURANCE - SPECIAL NUCLEAR MATERIALS SAFEGUARDS SUPPORT

CONTRACTORS: Argonne National Lab (4426)
HEDL (751)

FY 86 BUDGET: 5177

SCOPE: na

26. TITLE: CIVILIAN REACTOR DEVELOPMENT SUPPORT - SAFEGUARDS AND PROGRAM ASSURANCE - PROGRAM ASSURANCE PROJECT OFFICE OPERATIONS

CONTRACTOR: Oak Ridge National Lab

FY 86 BUDGET: 362

SCOPE: na

27. TITLE: CIVILIAN REACTOR DEVELOPMENT SUPPORT - REDUCED ENRICHMENT RESEARCH/TEST REACTOR - LEU FUEL DEMONSTRATION

CONTRACTOR: Argonne National Lab

FY 86 BUDGET: 4783

SCOPE: Low enriched uranium fuel demonstration.

28. **TITLE:** BREEDER REACTOR DEVELOPMENT PROGRAM - BREEDER COMPONENTS DEVELOPMENT

CONTRACTORS:
ETEC (2010)
Argonne National Lab (1340)
Oak Ridge National Lab (670)
Babcock & Wilcox (620)
HEDL (383)
Rockwell International (287)
Westinghouse (287)

FY 86 BUDGET:
Steam Generator Fabrication & Testing (287)
Automation Noise Surveillance & Testing (144)
EM Pump Coil/SG Booster Tube Modeling & Testing (1340)
Double Wall Tube Steam Generator (WNCD) Fab (287)
Helical Coil Tube Steam Generator Test Support (620)
In-Situ Nondestructive Inspection of IHX (130)
Nuclear Systems Materials Handbook (NSMH) Update (96)
Qualification of 9 Cr-1 Mo Steel for LMRs (300)
Risk Assessment Support--SAFR/PRISM Designs (212)
Steam Generator Test Installation (SCTI) Opns (2010)
Tech Transfer-Universities & Small Businesses (171)
Total Budget: 5597

SCOPE: EM pump coil/SG booster tube modeling and testing; helical coil tube steam generator testing; 9 Cr-1-Mo steel qualification tests; SCTI operations.

29. TITLE: BREEDER REACTOR DEVELOPMENT - FUEL PERFORMANCE AND SUPPLY

CONTRACTORS:
HEDL (13653)
Argonne National Lab (7,784)
Los Alamos (769)
Westinghouse (192)
General Electric (96)

FY 86 BUDGET:
Secure Automated Fuel (SAF) Fab Line Installation (8651)
Oxide Fuel Fab & Testing-SMA with Japan (866)
Qualify Mixed Oxide Fuel System (4131)
Update Long Lifetime Fuel (LIFE-4) (192)
IFR Safety Experiments & Analysis (3896)
IFR Fuel Performance Demonstration (3888)
Hot Cells Closeout - PIE (769)
Fuel & Blanket Assembly Performance (96)
ANS Fuels Meeting (5)
Total Budget: 22,494

SCOPE: Secure Automated Fuel fabrication line installation; oxide fuel fabrication and testing; mixed oxide fuel system qualification tests; IFR fuel performance demonstration, safety experiments, and analysis.

30. TITLE: BREEDER REACTOR DEVELOPMENT PROGRAM - REACTOR CORE DEVELOPMENT

CONTRACTORS:
Argonne National Lab (2540)
HEDL (2227)
Westinghouse (1435)
Rockwell International (195)

FY 86 BUDGET:
Control Driveline Expansion Device Design & Test (169)
AI Application to Control Systems (241)
Optimize PRISM/SAFR Metal Fuel Core Designs (440)
Safe Core Features Analysees (502)
Assessment of Device-Free Safe LMRs (305)
Evaluation of Licensing Strategies for Adv LMRs (115)
Fault Tolerant Control System Verification (120)
High Burnup Oxide Fuel Design (352)

Complete US/FRG/French Na Fires Data Exchange (26)
Installation and Testing of the SAF Line (890)
Core Design & Safety Methods Documentation (1491)
Power Plant Surveillance and Diagnostics (120)
Assess Robotics Applications for IFR Fuel Cycle (120)
Self Actuated Shutdown System (SASS) Fab & Test (433)
Core Assembly Seismic Analysis & Evaluation (86)
Install & Test Smart Instrumentation (899)
Total Budget: 6397

SCOPE: Core design and safety methods documentation; safe core features analyses; optimization studies of PRISM/SAFR fuel core designs; installation and testing of "smart" instrumentation channels; self-actuated shutdown system fabrication and testing.

31. TITLE: BREEDER REACTOR DEVELOPMENT PROGRAM - BREEDER FUEL CYCLE DEVELOPMENT

CONTRACTORS:
Oak Ridge National Lab (12,000)
Argonne National Lab (1614)
HEDL (625)
GA Technologies (500)
Los Alamos (40)
Sandia (40)

FY 86 BUDGET:
Breeder Casks Design Options Report (45)
Fuel Cycle & Plutonium Supply Analysis (240)
Fuel Cycle Integration Efforts (340)
Integrated Equipment Test (IET) Facility Opns (12,000)
Isotope Correlation Technique for Safeguards (80)
Breeder Spent Fuel Handling - Closeout (40)
Design Options for Fuel Cycle Facilities (40)
Proof-of-Breeding Analytical Support (1534)
HTGR Spent Fuel Treatment Options Analyses (500)
Total Budget: 15,619

SCOPE: LWR proof-of-breeding analytical support; HTGR spent fuel treatment options analyses; integrated cold testing and remote maintenance demonstrations; laboratory and hot cell experiments on fuel dissolution, feed clarification, and solvent extraction.

32. **TITLE:** UNIVERSITY RESEARCH PROGRAM
CONTRACTORS: Not yet designated.

FY 86 BUDGET: 6600 (Estimated)

Appendix D

Actual CY 1986 Nuclear Research and Development Program of the U.S. Department of Energy

EPRI CONTRACT LIST
CY 1985

Risk Assessment Program

1. TITLE: Soil-Structure Interaction
CONTRACTORS: NTS Engineering
AMOUNT: 5

2. TITLE: Development and Application of Advanced GO Methodology for Nuclear Safety Systems Assessment
CONTRACTORS: Energy, Inc.
AMOUNT: 153

3. TITLE: Seismic Testing and Analysis Program
CONTRACTORS: Anco Engineers, Inc.
Impell Corporation
Westinghouse Electric Corp.
Sargent & Lundy Engineers
AMOUNT: 86

4. TITLE: Foreign Experimental Data and Analysis
CONTRACTORS: Bechtel Group, Inc.
Power Computing Co.
AMOUNT: 35

5. TITLE: Nonlinear Finite Element Dynamic Computer Code Applications
CONTRACTORS: Hibbitt, Karlsson and Sorensen, Inc.
Power Computing Co.
AMOUNT: 176

6. TITLE: Ductile Support Design for Pipe Systems
CONTRACTORS: Bechtel Group, Inc.
AMOUNT: 103

7. TITLE: Initiate Modeling of Fluid-Structure Interaction Associated Large-Scale Jet Impingement Tests
CONTRACTORS: S. Levy Inc.
AMOUNT: 26

8. TITLE: Nuclear Power Plant Probabilistic Safety and Availability Analysis
CONTRACTORS: Pickard, Lowe & Garrick, Inc.
AMOUNT: 10

9. TITLE: Development and Application of Risk-Based Allowed Downtime Methodology
CONTRACTORS: Battelle-Columbus Laboratories
Delian Corporation
Various Cosponsors
AMOUNT: 347

10. TITLE: Development of Common Cause Failure Methodology and Data Base
CONTRACTORS: Los Alamos Technical Associates, Inc.
Pickard, Lowe & Garrick, Inc.
AMOUNT: 423

11. TITLE: Probabilistic Risk Assessment Methodology Development
CONTRACTORS: Gaver, Donald P., Prof.
NUS Corporation
Uribe, Luis C.
Koen, Billy
Hill, Joe
AMOUNT: 52

12. TITLE: Severe Accident Containment Integrity
CONTRACTORS: Anatech International Corp.
Construction Technology Labs
Winkleblack, R. K.
AMOUNT: 755

13. TITLE: Pipe Rupture and Depressurization Experiments
CONTRACTORS: Wyle Laboratories
AMOUNT: 318

14. TITLE: Large-Scale Seismic Experiment
CONTRACTORS: Taiwan Power Company
Kinemetrics Systems
Bechtel Group, Inc.
Anco Engineers, Inc.
AMOUNT: 682

15. TITLE: Plant System Interaction Analysis Methods
CONTRACTORS: Energy Incorporated
AMOUNT: 20

16. TITLE: Seismic Mitigation Systems
CONTRACTORS: Robert L. Cloud Associates, Inc.
AMOUNT: 204

17. TITLE: Simplified Structural Design and Analysis Methods
CONTRACTORS: Slagis, Gerald C.
Rockwell International Corp.
AMOUNT: 75

18. TITLE: Quantification of Seismic Design Conservatism and Its Cost Impact
CONTRACTORS: Anderson, Donald
AMOUNT: 22

19. TITLE: Seismic Intensity and Attenuation
CONTRACTORS: Internal Use Only
AMOUNT: 542

20. TITLE: Reliability Analysis Software Support and Development
CONTRACTORS: Science Applications International
Power Computing Company
AMOUNT: 262

21. TITLE: Use of PRA Methods for Enhancing Operational Safety
CONTRACTORS: Energy Incorporated
Los Alamos Technical Associates, Inc.
Science Applications International
GPU Nuclear Corporation
Various Cosponsors
Arizona Public Service Co.
AMOUNT: 646

22. TITLE: Seismic Design Ground Motion for Nuclear Power Plants
CONTRACTORS: Univ. of California at San Diego
Stanford University
Jack R. Benjamin & Associates, Inc.
Woodward-Clyde Consultants
Stanford University
Teledyne Geotech
Earthquest
Geomatrix Consultants
Brigham Young University
Risk Engineering, Inc.
Power Computing Company
Pacific Geophysics, Inc.
Tsai, Yi-Ben
Science Applications International
AMOUNT: 1,121

23. TITLE: Power Piping during and after Earthquakes
CONTRACTORS: EQE Incorporated
AMOUNT: 100

24. TITLE: Human Reliability Methodology and PRA Review
CONTRACTORS: NUS Corporation
AMOUNT: 540

25. TITLE: Regulatory Impact Assessment
CONTRACTORS: Science Applications International
Brookhaven National Laboratory
Technology Application Inc.
Safety & Reliability Optimization
AMOUNT: 151

26. TITLE: Nuclear Plant Reevaluation for Earthquakes to Quantify Seismic Margins
CONTRACTORS: NTS/Structural Mechanics Associates
Pickard, Lowe & Garrick, Inc.
EQE Incorporated
ANCO Engineers, Inc.
URS/John Blume & Associates
AMOUNT: 299

27. **TITLE:** Improved Loading Input Due to Inelastic Response of Structures
CONTRACTORS: URS/John Blume & Associates
AMOUNT: 116

Source Term Program

28. **TITLE:** Degraded Core Interactions
CONTRACTORS: Univ. of California at Los Angeles
Argonne National Labs
Univ. of California at Berkeley
Univ. of Wisconsin
AMOUNT: 371

29. **TITLE:** Hydrogen Generation, Combustion, and Management in Severe Postulated Accidents
CONTRACTORS: Astron Research & Engineering
AMOUNT: 10

30. **TITLE:** In-Vessel Severe Accident Progression and Containment Loadings
CONTRACTORS: Science Applications International
Massachusetts Institute of Technology
University of Illinois
AMOUNT: 230

31. **TITLE:** Removal of Radionuclides by Water Pools Under Severe Accident Conditions
CONTRACTORS: Battelle-Columbus Laboratories
Science Applications International
Otha Inc.
AMOUNT: 392

32. **TITLE:** Activity Transport & Diffusion in Two-Phase Flows Under Accident Conditions
CONTRACTORS: Battelle-Columbus Laboratories
Li, Jun
Power Computing Company
Sher, Rudolph
AMOUNT: 189

33. TITLE: High Concentration Aerosol Modeling and Experiments
CONTRACTORS: Rockwell International Corp.
Studsvik Energiteknik AB
U.S. Department of Energy
Intermountain Technologies, Inc.
H.M. Associates, Ltd.
Argonne National Labs
Sher, Rudolph
Golay, Michael
Stone & Webster Eng. Corp.
Technical Research Centre of Finland
Commissariat a L'Energie Atomique
Institute for Reactor Research
ENEA-C.R.E. Casacia
Japan Atomic Energy Research Inst.
SKI
United Kingdom Atomic Energy Authority
New York Power Authority
AMOUNT: 1,636

34. TITLE: Fission Product Chemical Behavior Under Severe Accident Conditions
CONTRACTORS: Argonne National Labs
Ontario Hydro
AMOUNT: 730

35. TITLE: Thermal-Hydraulic Modeling of Primary Cool System Following Severely Degraded Core Accident
CONTRACTORS: Science Applications International
Westinghouse Electric Corp.
Argonne National Labs
Power Computing Company
Bieniarz, Peter
AMOUNT: 807

36. TITLE: In Reactor Source Term Experiments
CONTRACTORS: Argonne National Labs
Ontario Hydro
AMOUNT: 999

37. TITLE: Degraded Core Accident Studies
CONTRACTORS: Lawrence Berkeley Lab
Leverett, Miles C.
Fauske & Associates, Inc.
AMOUNT: 117

38. **TITLE:** Technical Support for Current Issues
CONTRACTORS: Northwestern University
AMOUNT: 62

39. **TITLE:** Water Distribution in LWR Primary Coolant System and Containment During a Severe Accident
CONTRACTORS: Science Applications International
H.M. Associates, Ltd.
Jaycor
Battelle-Northwest
Intermountain Technologies, Inc.
Power Computing Company
Federal Data Systems, Inc.
Almenas, Kazys
Energy Incorporated
Kernforschungzentrum Karlsruhe GMBH
Systems Control, Inc.
Expert-Ease Systems
AMOUNT: 394

40. **TITLE:** Corium-Concrete Interaction
CONTRACTORS: Maly, Jaromir
Argonne National Labs
Massachusetts Institute of Technology
AMOUNT: 278

41. **TITLE:** Methodology and Applications for Severe Accident Analyses
CONTRACTORS: Science Applications International
Fauske & Associates, Inc.
Stone & Webster Eng. Corp.
Jaycor
Switzer, Paul
Federal Data Systems, Inc.
AMOUNT: 671

42. **TITLE:** Fission Product Aerosol Transport Development and Implementation
CONTRACTORS: Rockwell International Corp.
Fauske & Associates, Inc.
AMOUNT: 131

43. TITLE: Coupled Aerosol/Thermal-Hydraulic Methodology and Procedures for Severe Accident Analysis
CONTRACTORS: Science Applications International
AMOUNT: 104

44. TITLE: Analysis of Postulated BWR ATWS Accidents
CONTRACTORS: General Electric Co.
Maly, Jaromir
AMOUNT: 152

Analytical Methods and Verification Program

45. TITLE: Development and Application of the EPRI DATATRAN Executive Code System
CONTRACTORS: Technology Development of California
Intermountain Technologies, Inc.
AMOUNT: 65

46. TITLE: Distribution and Control of Nuclear Computer Codes
CONTRACTORS: Power Computing Company
AMOUNT: 40

47. TITLE: Two-Phase Flow Analysis Related to Reactor Safety
CONTRACTORS: Jaycor
AMOUNT: 99

48. TITLE: Development of a System Transient Simulator
CONTRACTORS: Energy Incorporated
AMOUNT: 700

49. TITLE: Development of Models for Reactor Transient Effects
CONTRACTORS: Energy Incorporated
AMOUNT: 88

50. TITLE: Extensions of the Advanced Methodology Program (ARMP) for Fuel Management Applications
CONTRACTORS: Science Applications International
AMOUNT: 165

51. TITLE: Nuclear Power Plant Operations Modeling
CONTRACTORS: Power Computing Company
AMOUNT: 20

52. TITLE: Core Performance Benchmarking
CONTRACTORS: Science Applications International
AMOUNT: 46

53. TITLE: Advanced In-Core Fuel Management Optimization Methodology for PWRs
CONTRACTORS: Science Applications International
AMOUNT: 60

54. TITLE: Fuel Management Physics Capability Enhancement
CONTRACTORS: S. Levy Inc.
Swuco, Inc.
Williams, Mark
AMOUNT: 307

55. TITLE: Analytical Methods for Transient Fuel Behavior
CONTRACTORS: Anatech International Corp.
AMOUNT: 40

56. TITLE: Benchmark Analysis of Core Bundle Thermal-Hydraulic Experiments
CONTRACTORS: Argonne National Labs
AMOUNT: 36

57. TITLE: Development of an Advanced Methodology in Dosimetry Applications
CONTRACTORS: Martin Marietta Energy Systems, Inc.
AMOUNT: 99

58. TITLE: A Qualified Core Thermal Hydraulics Analysis Code for Utility Applications
CONTRACTORS: Battelle-Northwest
Wang Software Service
AMOUNT: 371

59. TITLE: Assessment and Application of Transient Fuel Behavior Computer Codes
CONTRACTORS: Texas Engineering Experiment Station
AMOUNT: 20

60. TITLE: Core Power Distribution Benchmark Code Development
CONTRACTORS: G.R.P. Consulting, Inc.
AMOUNT: 37

61. TITLE: Qualification of New Nuclear Data Libraries for the ARMP Lattice Physics Programs
CONTRACTORS: Martin Marietta Energy Systems, Inc.
AMOUNT: 15

62. TITLE: RASP: Reactor Analysis Support Package
CONTRACTORS: S. Levy Inc.
Technology Development of California
Science Applications International
Tennessee Valley Authority
Energy Incorporated
Power Computing Company
Pickard, Lowe, & Garrick, Inc.
G.R.P. Consulting, Inc.
Delian Corporation
Diamond, David J.
Turinsky, Paul
Combustion Engineering, Inc.
AMOUNT: 1,079

63. TITLE: Development of a Nodal-Based 3-D Transient Capability for Detailed LWR Analysis
CONTRACTORS: S. Levy Inc.
AMOUNT: 93

64. TITLE: Nuclear Power Division Internal Computer Usage
CONTRACTORS: Power Computing Company
Lawrence Berkeley Lab
AMOUNT: 205

65. TITLE: Core Physics Methods Development and Validation
CONTRACTORS: Studsvik Energiteknik AB
S. Levy Inc.
AMOUNT: 40

66. TITLE: Fuel Cycle Scoping Capability Development
CONTRACTORS: Purdue Research Foundation
AMOUNT: 45

Safety Control and Testing Program

67. **TITLE:** BWR Full Integral Simulation Test (BWR-FIST) Program
CONTRACTORS: General Electric Co.
Arizona State University
University of Michigan
AMOUNT: 151

68. **TITLE:** Reactor Safety R&D Planning and Evaluation Support
CONTRACTORS: Intermountain Technologies, Inc.
Atomic Energy of Canada, Ltd.
Power Computing Company
AMOUNT: 17

69. **TITLE:** On-Line Analysis of Power Plant Alarms and Disturbances
CONTRACTORS: Nuclear Software Services, Inc.
AMOUNT: 20

70. **TITLE:** PWR Reflooding and System Thermal-Hydraulic Tests
CONTRACTORS: Science Applications International
Boeing Computer Service
AMOUNT: 81

71. **TITLE:** Multidimensional Thermal-Hydraulic Analysis of Steam Generators
CONTRACTORS: Cham of North America, Inc.
Wang Software Service
Westinghouse Electric Corp.
AMOUNT: 140

72. **TITLE:** Basic Investigation and Qualification of Single-Channel Counter-Current Flooding Models
CONTRACTORS: Univ. of California at Berkeley
AMOUNT: 86

73. **TITLE:** BWR Stability Analysis and Prediction
CONTRACTORS: Asea-Atom
University of Washington
AMOUNT: 87

74. **TITLE:** On-Line Nuclear Power Distribution
CONTRACTORS: Systems Control, Inc.
AMOUNT: 108

75. **TITLE:** Analysis of Power Plant Tests with Advanced Systems Codes Cracking
CONTRACTORS: S. Levy Inc.
Intermountain Technologies, Inc.
Middle South Services, Inc.
Louisiana Power & Light
AMOUNT: 66

76. **TITLE:** PWR - Power Shape Monitoring System
CONTRACTORS: Systems Control, Inc.
PSE&G Research Corp.
Blake Scientific, Inc.
Utility Associates International
AMOUNT: 197

77. **TITLE:** Heat Transfer above the Two-Phase Mixture Level under Core Uncovery Conditions
CONTRACTORS: Purdue Research Foundation
AMOUNT: 42

78. **TITLE:** Steam Generator Simulation Experiments Under Dynamic Thermal Conditions
CONTRACTORS: Westinghouse Electric Corp.
Massachusetts Institute of Technology
AMOUNT: 323

79. **TITLE:** Analytical Simulations for Reactor Accident Analysis
CONTRACTORS: Babcock & Wilcox Co.
General Physics Corp.
Energy Incorporated
AMOUNT: 104

80. **TITLE:** In-Pile Tests and Analysis of Heat Transfer in Fuel Bundles Under Accident Conditions
CONTRACTORS: Rowe & Associates
AMOUNT: 25

81. **TITLE:** Thermal Mixing Due to ECC Injection
CONTRACTORS: Creare Research and Development, Inc.
Univ. of California at Los Angeles
AMOUNT: 21

82. TITLE: Nuclear Power Plant Signal Validation
CONTRACTORS: Westinghouse Electric Corp.
Tennessee Valley Authority
AMOUNT: 369

83. TITLE: PWR Pump Analysis and Testing
CONTRACTORS: Tetra Tech, Inc.
EG&G Idaho, Inc.
Power Computing Company
AMOUNT: 111

84. TITLE: PWR and BWR Real-Time Signal Validation Demonstrations
CONTRACTORS: Babcock & Wilcox Co.
Northeast Utilities Service Co.
AMOUNT: 201

85. TITLE: Critical Flow Through Small Breaks
CONTRACTORS: Dartmouth College
EG&G Idaho, Inc.
AMOUNT: 110

86. TITLE: Experimental Study of PWR System Response in Small Break and Overcooling Transients
CONTRACTORS: SRI International
Jaycor
AMOUNT: 378

87. TITLE: Validation of Emergency Procedures Tracking System
CONTRACTORS: Nuclear Software Services, Inc.
Operations Engineering, Inc.
AMOUNT: 178

88. TITLE: Development and Evaluation of Component Models
CONTRACTORS: Jaycor
AMOUNT: 84

89. TITLE: Flow Regimes in Large Pipes with Entrance Effects
CONTRACTORS: Science Applications International
AMOUNT: 75

90. **TITLE:** Compact Plant Analyzer Development
CONTRACTORS: Systems Control, Inc.
Duke Power Company
S. Levy Inc.
Horne, Charles P.
AMOUNT: 322

91. **TITLE:** Integrated Tests for Babcock & Wilcox PWR System Design
CONTRACTORS: Babcock & Wilcox Co.
Science Applications International
Dartmouth College
Intermountain Technologies, Inc.
AMOUNT: 649

92. **TITLE:** LOFT Consortium--Reactor Safety Experiments
CONTRACTORS: U.S. Department of Energy
Jaycor
Intermountain Technologies, Inc.
AMOUNT: 502

93. **TITLE:** LWR Digital Control and Diagnostics
CONTRACTORS: Charles Stark Draper Lab., Inc.
Science Applications International
Los Alamos Technical Associates, Inc.
Atomic Energy of Canada, Ltd.
Northern States Power Co.
AMOUNT: 508

94. **TITLE:** Investigation of Steam Generator Tube Rupture Thermal Hydraulics in PWRs
CONTRACTORS: Acurex Corporation
Northwestern University
Science Applications International
Boeing Computer Service
AMOUNT: 209

95. **TITLE:** Knowledge-Based Expert Systems for Safety Control and Fuel Management
CONTRACTORS: Intellicorp
Technology Application, Inc.
AMOUNT: 386

96. **TITLE:** Diagnosis of Internals Vibration of Reactor Systems
CONTRACTORS: Martin Marietta Energy Systems, Inc.
AMOUNT: 40

97. TITLE: LWR Digital Control and Fault-Tolerant Computer Technology
CONTRACTORS: Argonne National Labs
Atomic Energy of Canada, Ltd.
AMOUNT: 83

Component Reliability Program

98. TITLE: Development and Evaluation of an Acoustic Imaging System for Field Application
CONTRACTORS: Sigma Research
AMOUNT: 8

99. TITLE: Portable Radiographic System for In-Service and Repair Inspection
CONTRACTORS: Schonberg Radiation Corp.
AMOUNT: 23

100. TITLE: Feasibility of and Methodology for Thermal Annealing an Embrittled Reactor Vessel
CONTRACTORS: Westinghouse Electric Corp.
Univ. of California at Santa Barbara
AMOUNT: 131

101. TITLE: Control of Residual Stresses in Repair Welding of Heavy Section Steel Nozzles
CONTRACTORS: United Kingdom Welding Institute
AMOUNT: 19

102. TITLE: Simplified Prediction of Elastic-Plastic Fracture
CONTRACTORS: General Electric Co.
AMOUNT: 92

103. TITLE: The Effect of Specimen Size and Configuration on Fracture Toughness and Ductile Instability
CONTRACTORS: Westinghouse Electric Corp.
AMOUNT: 10

104. TITLE: In-Service Inspection Data Analysis
CONTRACTORS: Colorado State University
Power Computing Company
AMOUNT: 126

105. **TITLE:** Structural Reliability Methodology (Initial Study)
CONTRACTORS: Strategic Decisions Group
Pickard, Lowe & Garrick, Inc.
Structural Integrity Associates
Lefohn, Allen S.
AMOUNT: 55

106. **TITLE:** Reliability of Piping and Fittings
CONTRACTORS: Fracture Control Corp.
General Electric Co.
AMOUNT: 640

107. **TITLE:** TMI-2 Mechanical Component Information and Examination Programs
CONTRACTORS: Pentek, Inc.
Carnegie-Mellon University
AMOUNT: 90

108. **TITLE:** EPRI Nondestructive Evaluation (NDE) Center
CONTRACTORS: J. A. Jones Applied Research Co.
Combustion Engineering Inc.
Coecorp
AMOUNT: 4,157

109. **TITLE:** Requalification of Pressure Retaining Components Following Emergency and Faulted Transients
CONTRACTORS: Teledyne Engineering Services
Babcock & Wilcox Co.
AMOUNT: 70

110. **TITLE:** Codes, Standards, and Technology Transfer
CONTRACTORS: Failure Analysis Associates
Wessel, Edward T.
Central Electricity Generating Board
Babcock & Wilcox Co.
Fracture Control Corp.
Teledyne Engineering Services
G. Robert Odette
Impell Corporation
Smith, Edwin
Robert L. Cloud Associates, Inc.

Reedy Associates
Anamet Laboratory
Novetech Corporation
Structural Integrity Associates
Metal Properties Council, Inc.
Westinghouse Electric Corp.
AMOUNT: 461

111. TITLE: Reactor Coolant Systems Decontamination and Dose Reduction
CONTRACTORS: Quadrex Computer Systems, Inc.
Pacific Nuclear Systems & Services
Battelle Pacific Northwest Lab.
AMOUNT: 229

112. TITLE: Support Structure and Pressure Boundary Component Reliability
CONTRACTORS: Aptech Engineering Services, Inc.
Raymond Bolting Services
AMOUNT: 254

113. TITLE: Long-Term Inspection Requirements of Nuclear Units
CONTRACTORS: Nutech Engineers
Science Applications International
Vintek, Inc.
AMOUNT: 64

114. TITLE: Near Surface Underclad Crack Detection
CONTRACTORS: Qualcorp, Inc.
Shanker, Ramesh
Westinghouse Electric Corp.
AMOUNT: 377

115. TITLE: In-Service Inspection of Dissimilar Metal Welds and Bolts in Support Structures
CONTRACTORS: Southwest Research Institute
Battelle-Northwest
AMOUNT: 88

116. TITLE: Pressure Boundary Reliability
CONTRACTORS: Combustion Engineering Inc.
Southwest Research Institute
Massachusetts Institute of Technology
AMOUNT: 354

117. TITLE: Simplified Piping Design Methods
CONTRACTORS: Duke Power Company
AMOUNT: 20

118. TITLE: Nozzle and Pipe Inspection Technology
CONTRACTORS: Mayer, Walter G.
Amdata Systems, Inc.
Ultrasonics International, Inc.
Vitek, Inc.
Structural Integrity Associates
NES/Dynacon Systems, Inc.
Aptech Engineering Services, Inc.
Southwest Research Institute
Drexel University
AMOUNT: 562

119. TITLE: Material Property Variability
CONTRACTORS: Materials Research/Computer Simulat.
Product and Systems Engineering
Battelle-Columbus Laboratories
SRI International
AMOUNT: 345

120. TITLE: Integrity Related Remedial Actions Evaluation
CONTRACTORS: Combustion Engineering Inc.
Southern California Edison Co.
AMOUNT: 38

121. TITLE: Development of Advanced Methods of Structural Analysis
CONTRACTORS: Impell Corporation
General Electric Co.
Combustion Engineering Inc.
Techint Incorporated
Failure Analysis Associates
Novetech Corporation
AMOUNT: 299

122. TITLE: TMI-2 Recovery: Technology Transfer
CONTRACTORS: Pentek, Inc.
Burns & Roe, Inc.
Vaile, Robert B.
Grove Engineering
AMOUNT: 869

123. TITLE: Advanced Steam Generator ISI
CONTRACTORS: Battelle Memorial Institute
Combustion Engineering Inc.
University of Washington
Colorado State University
AMOUNT: 73

124. TITLE: Ultrasonic Energy Propagation Studies
CONTRACTORS: Ames Laboratory
Colorado State University
Illinois Institute of Technology
AMOUNT: 190

125. TITLE: Fatigue Monitoring on Plant Components
CONTRACTORS: Robert L. Cloud Associates, Inc.
EG&G Idaho, Inc.
Structural Integrity Associates
General Electric Co.
AMOUNT: 146

126. TITLE: Systematic Snubber Reduction
CONTRACTORS: Teledyne Engineering Services
AMOUNT: 72

LWR Fuel & Spent Fuel Storage Program

127. TITLE: Halden Research Program Support
CONTRACTORS: Institute for Energiteknikk
AMOUNT: 152

128. TITLE: Fuel Rod Performance Tests
CONTRACTORS: Science Applications International
AMOUNT: 10

129. TITLE: EPRI/Combustion Engineering Cooperative Program on PWR Fuel Performance
CONTRACTORS: Combustion Engineering Inc.
AMOUNT: 59

130. TITLE: EPRI/Westinghouse Cooperative Program on PWR Fuel Performance
CONTRACTORS: Westinghouse Electric Corp.
AMOUNT: 50

131. **TITLE:** Uniform and Nodular Waterside Corrosion of Zircaloy
CONTRACTORS:
Battelle-Northwest
Asea-Atom
Sandvik, Inc.
University of Illinois
S. Levy Inc.
Battelle Pacific Northwest Laboratory
Univ. of California at Berkeley
Li, C. Y.
AMOUNT: 287

132. **TITLE:** Support of EPRI Fuel Performance Data Base
CONTRACTORS:
S. Levy Inc.
Utility Associates International
AMOUNT: 123

133. **TITLE:** Fuel-Performance Economics and Reliability Assessment, Resolution of In-Reactor Issues
CONTRACTORS:
Babcock & Wilcox Co.
Combustion Engineering Inc.
AMOUNT: 26

134. **TITLE:** Demonstration of Pellet-Cladding Interaction (PCI) - Resistant Fuel Rod Design
CONTRACTORS:
Exxon Nuclear Co., Inc.
Alfred University
Stanford University
Babcock & Wilcox Co.
AMOUNT: 116

135. **TITLE:** Demonstration of Extended Burnup Fuel Designs
CONTRACTORS:
Massachusetts Institute of Technology
Central Electricity Generating Board
Belgonucleaire
British Nuclear Fuels, Ltd.
Gebco Engineering
Power Computing Company
AMOUNT: 128

136. TITLE: LWR Control Materials
CONTRACTORS: Asea-Atom
Stoller Corp., S. M.
Westinghouse Electric Corp.
Duke Power Company
AMOUNT: 372

137. TITLE: Fission Product Migration and Release Behavior in U02 Fuels
CONTRACTORS: Riso National Laboratory
Anatech International Corp.
Combustion Engineering Inc.
AMOUNT: 100

138. TITLE: Improved NDE Capabilities for Reactor Core Components
CONTRACTORS: National Nuclear Corp.
AMOUNT: 1

139. TITLE: Core Materials Performance Forecasting and Control
CONTRACTORS: Battelle-Northwest
Combustion Engineering Inc.
S. Levy Inc.
AMOUNT: 201

140. TITLE: Spent Fuel Behavior Under Storage Conditions
CONTRACTORS: Atomic Energy of Canada, Ltd.
Battelle-Northwest
Jones, Robert H.
Coecorp
AMOUNT: 60

141. TITLE: Nuclear Fuel Industry Research
CONTRACTORS: NFIR
AMOUNT: 350

142. TITLE: Characterization and Reduction of Fuel and Core Component Failures in LWRs
CONTRACTORS: Battelle Pacific Northwest Laboratory
Babcock & Wilcox Co.
AMOUNT: 131

143. **TITLE:** Spent Fuel Consolidation Technology Demonstration
CONTRACTORS: Northeast Utilities Service Co.
Fracture Control Corp.
Graf, Walter
AMOUNT: 172

144. **TITLE:** Spent Fuel Storage Cask Technology and Demonstration
CONTRACTORS: Transnuclear Inc.
Battelle-Northwest
Virginia Electric & Power Co.
AMOUNT: 1,039

145. **TITLE:** High-Level Waste Technical, R&D, and Safety Assessment
CONTRACTORS: Analytic Sciences Corp.
Kaiser Engineers California Corp.
Golder Associates Incorporated
AMOUNT: 177

146. **TITLE:** Spent Fuel Silo Storage Demonstration
CONTRACTORS: Carolina Power & Light Co.
AMOUNT: 350

147. **TITLE:** Nuclear Fuel Reliability during Load Follow Operation in LWRs
CONTRACTORS: Belgonucleaire
S. M. Stoller Corp.
AMOUNT: 132

148. **TITLE:** Mitigation of Irradiation - Assisted SCC in Core Components
CONTRACTORS: Structural Integrity Associates
General Electric Co.
AMOUNT: 190

149. **TITLE:** Storage Demonstrations Technical Support
CONTRACTORS: E.R. Johnson Associates, Inc.
Fracture Control Corp.
Anatech International Corp.
AMOUNT: 170

Corrosion Control Program

150. TITLE: Steam Generator Model Boiler Program
CONTRACTORS: SRI International
AMOUNT: 15

151. TITLE: Corrosion Programs to Support Reliability of Nuclear LWR Systems
CONTRACTORS: Ohio State University
Massachusetts Institute of Tech.
Rensselear Polytechnic Institute
S.M. Stoller Corp.
AMOUNT: 302

152. TITLE: Chemical Reaction Data for Predicting Corrosion Behavior of LWR Materials in High Temperature Water
CONTRACTORS: Power Computing Company
AMOUNT: 1

153. TITLE: Corrosion Fatigue Characterization of Reactor Pressure Vessel Steels
CONTRACTORS: Babcock & Wilcox Co.
Fracture Control Corp.
SRI International
Gustafsson, Ulla
Structural Integrity Associates
Framatome
Cise Spa
AMOUNT: 461

154. TITLE: Alternate PWR Steam Generator Tubing Evaluation
CONTRACTORS: Vallourec, Inc.
AMOUNT: 20

155. TITLE: Evaluation of the Use of Inconel 690 in BWR Components
CONTRACTORS: Southwest Research Institute
AMOUNT: 19

156. TITLE: Crevice Corrosion
CONTRACTORS: Rensselear Polytechnic Inst.
AMOUNT: 77

157. **TITLE:** Corrosion Resistance of Thermally Treated Alloy 600
CONTRACTORS: Westinghouse Electric Corp.
AMOUNT: 164

158. **TITLE:** Advanced Methodology for Improving Turbine Disc Lifetimes
CONTRACTORS: Westinghouse Electric Corp.
AMOUNT: 3

159. **TITLE:** Hydrogen Water Chemistry for BWRs
CONTRACTORS: General Electric Co.
Advanced Process Technology
Commonwealth Research Corp.
Amdata Systems, Inc.
AMOUNT: 1,685

160. **TITLE:** Prediction of Corrosion-Assisted Crack Growth in Nuclear Power Plant Components
CONTRACTORS: Westinghouse Electric Corp.
Battelle-Columbus Laboratories
Failure Analysis Associates
General Electric Co.
Metal Properties Council Inc.
Research Inst. for Strength & Fract.
AMOUNT: 837

161. **TITLE:** Metallurgical Analysis and Evaluation of Service Failures of Nuclear Power Components
CONTRACTORS: Babcock & Wilcox Co.
General Electric Co.
Battelle-Columbus Laboratories
AMOUNT: 29

162. **TITLE:** Automatic Remote Welding
CONTRACTORS: Georgia Power Company
AMOUNT: 25

163. **TITLE:** High-Purity Steels for Utility Components
CONTRACTORS: Bethlehem Steel Corporation
AMOUNT: 24

164. TITLE: Examination and Testing of a Retired Steam Generator
CONTRACTORS: Battelle-Northwest
AMOUNT: 200

165. TITLE: Prediction of Localized Corrosion Rates in Steam Generators
CONTRACTORS: Brigham Young University
San Diego State Univ. Foundation
Paul Cohen
W. T. Lindsay, Jr.
SC&A, Inc.
S-Cubed
McBride, Donald
Atomic Energy of Canada, Ltd.
AMOUNT: 328

166. TITLE: SCC of Cold Worked Alloy 600 Steam Generator Tubes
CONTRACTORS: S. Levy Inc.
Rutgers
Bogaerts, Walter
Battelle Pacific Northwest Lab.
Commissariat a L'Energie Atomique
Wolverine Metal Company, Inc.
Somitomo Metal America, Inc.
AMOUNT: 123

167. TITLE: Optimized Heat Treatment for Alloy X-750 and Other High Strength Age-Hardenable Alloys
CONTRACTORS: Babcock & Wilcox Co.
Westinghouse Electric Corp.
Kraftwerk Union Aktiengesellschaft
AMOUNT: 100

168. TITLE: BWR Water Chemistry Impurity Studies
CONTRACTORS: Asea-Atom
General Electric Co.
AMOUNT: 1,223

169. TITLE: Full-Scale Instrumented Steam Generator Tests and Analyses
CONTRACTORS: Combustion Engineering Inc.
AMOUNT: 105

170. TITLE: Improved Steam Generator Water Chemistry--Field Studies
CONTRACTORS: NWT Corporation
Atomic Energy of Canada, Ltd.
AMOUNT: 151

171. TITLE: Sludge Removal in PWR Steam Generators
CONTRACTORS: Energy Management Sources
Dominion Engineering, Inc.
Babcock & Wilcox Co.
London Nuclear Services, Inc.
Combustion Engineering Inc.
Westinghouse Electric Corp.
Empire State Elec. Energy Research
AMOUNT: -9

Plant Availability Program

172. TITLE: On-Line Vibration Diagnostics for Power Plant Machinery
CONTRACTORS: Radian Corporation
AMOUNT: 155

173. TITLE: Primary Coolant Pump Seal Improvements
CONTRACTORS: Atomic Energy of Canada, Ltd.
AMOUNT: 21

174. TITLE: Human Factors Operational Guidelines and Primer
CONTRACTORS: Essex Corporation
AMOUNT: 200

175. TITLE: Set Point Testing of Safety Valves with Alternative Test Media or Methods
CONTRACTORS: J.A. Jones Applied Research Co.
AMOUNT: 13

176. TITLE: Evaluation of Advanced Alarm Handling Approaches
CONTRACTORS: M.P.R. Associates, Inc.
AMOUNT: 135

177. **TITLE:** Work Structure and Performance
CONTRACTORS: Essex Corporation
AMOUNT: 112

178. **TITLE:** Failure Analysis of Nuclear Plant Components
CONTRACTORS: Schonberg Radiation Corp.
Heat Exchanger Systems, Inc.
AMOUNT: 41

179. **TITLE:** Human Engineering Guidelines for Computer-Generated Displays Used in Power Plants
CONTRACTORS: Union Carbide Corp.
Search Technology, Inc.
The Hartford Graduate Center
Blake, Tyler
AMOUNT: 59

180. **TITLE:** Robot Applications for Nuclear Power Plants
CONTRACTORS: Advanced Resource Development Corp.
H.B. Meieran Associates
Odetics, Inc.
AMOUNT: 552

181. **TITLE:** Key Valves
CONTRACTORS: Foster-Miller Associates, Inc.
AMOUNT: 542

182. **TITLE:** On-Line Monitoring and Diagnostics for Diesel Generators
CONTRACTORS: Southwest Research Institute
AMOUNT: 35

183. **TITLE:** Guidelines for the Application of Computer-Assisted Instruction (CAI)
CONTRACTORS: Search Technology, Inc.
Arinc Research Corp.
AMOUNT: 227

184. **TITLE:** On-Line Monitoring and Diagnostics for Submerged Vertical Shaft Pumps
CONTRACTORS: Shaker Research Corp.
AMOUNT: 148

185. **TITLE:** Nuclear Plant Performance Improvement
CONTRACTORS: Combustion Engineering Inc.
Mollerus Engineering
AMOUNT: 90

186. **TITLE:** Field Data Requirements to Predict Stress Corrosion Cracking
CONTRACTORS: General Electric Co.
Power Computing Company
AMOUNT: 85

187. **TITLE:** Field Hardened Instruments and Electrical Components for Nuclear Plant Applications
CONTRACTORS: Science Applications International
Foster-Miller Associates, Inc.
AMOUNT: 409

188. **TITLE:** Guidelines for Surveillance Testing of Standby Equipment
CONTRACTORS: Mollerus Engineering
Gilcrest, James
AMOUNT: 9

189. **TITLE:** Data Consolidation for Research Project Planning
CONTRACTORS: NUS Corporation
S. M. Stoller Corp.
AMOUNT: 173

190. **TITLE:** Secondary Side Component/System Improvement
CONTRACTORS: Raymond Engineering Inc.
AMOUNT: 25

191. **TITLE:** Long-Range Research Support for System Performance Program
CONTRACTORS: Carnegie-Mellon University
Wayne State University
University of Pennsylvania
AMOUNT: 189

192. **TITLE:** Reliability and Lifetime Extension of LP Discs
CONTRACTORS: Southwest Research Institute
Failure Analysis Associates
AMOUNT: 22

193. TITLE: Maintenance Equipment Applications Center
CONTRACTORS: J.A. Jones Applied Research Co.
Video by Design
AMOUNT: 505

194. TITLE: Nuclear Plant Maintenance Improvements
CONTRACTORS: Dominion Engineering, Inc.
Battelle Memorial Institute
Studio 16 Communications, Inc.
AMOUNT: 175

195. TITLE: Evaluation of the Turbine Protection System
CONTRACTORS: Foster-Miller Associates, Inc.
AMOUNT: 105

196. TITLE: Loose Parts Monitoring System Improvements
CONTRACTORS: Science Applications International
AMOUNT: 116

197. TITLE: Studies of Man-Machine Interface Problems in Maintenance
CONTRACTORS: Westinghouse Electric Corp.
Seminara, Joseph
Georgia State University
AMOUNT: 126

Nuclear Plant Life Extension & Constructibility Program

198. TITLE: Fire Retardant Lubricant for Reactor Coolant Pump Motors
CONTRACTORS: Westinghouse Electric Corp.
AMOUNT: 217

199. TITLE: Equipment Qualification Program
CONTRACTORS: NUS Corporation
Los Alamos Technical Associates, Inc.
Wyle Laboratories
University of Connecticut
EQE Incorporated
Anco Engineers, Inc.

URS/John Blume & Associates
Impell Corporation
Washington Public Power Supply System
Hartford Valve & Fitting Co.
Far West Technology, Inc.
Mazzella Wire Rope & Supply, Inc.
McCarty & Sons, Inc.
Fisher Scientific
Economy Electric Supply
Automatic Switch Company
Brookstone Company
Bolt, Robert
Nutech International
AMOUNT: 632

200. **TITLE:** Remote Indication of Degradation of Fire Retardant Lubricant LMFBRs
CONTRACTORS: Mechanical Technology, Inc.
U.S. Department of Energy
AMOUNT: 131

201. **TITLE:** Maintainability Studies
CONTRACTORS: Pennsylvania State University
General Physics Corp.
Westinghouse Electric Corp.
AMOUNT: 253

202. **TITLE:** TMI-2 Equipment Qualification Methodology Testing
CONTRACTORS: Westinghouse Electric Corp.
AMOUNT: 10

203. **TITLE:** Studies of Nuclear Plant Operability and Maintainability
CONTRACTORS: Stone & Webster Eng. Corp.
AMOUNT: 36

204. **TITLE:** Electrical and Instrumentation Constructability for Nuclear Plant Applications
CONTRACTORS: J.A. Jones Applied Research Co.
Spiewak, Irving
AMOUNT: 26

205. **TITLE:** Piping Design and Construction Technique
CONTRACTORS: Reedy Associates
AMOUNT: 1

206. **TITLE:** Guidelines for Applying Computer-Aided Design Systems to Generating Plant Projects
CONTRACTORS: Clyde Boswell Tatum
Duke Power Company
Consumers Power Company
AMOUNT: 475

207. **TITLE:** LWR Plant Life Extension
CONTRACTORS: Virginia Electric & Power Co.
Northern States Power Co.
Grove Engineering
Multiple Dynamics Corporation
Structural Integrity Associates
S. M. Stoller Corp.
Gebco Engineering
Ishikawajima - Harima Heavy Industries
AMOUNT: 589

Low Level Waste and Coolant Technology Program

208. **TITLE:** Dosimetry Measurements of Neutron and Gamma Ray Fluxes in the Reactor Cavity of LWR's
CONTRACTORS: University of Arkansas
AMOUNT: 50

209. **TITLE:** BWR Radiation Assessment and Control
CONTRACTORS: General Electric Co.
Commonwealth Research Corporation
AMOUNT: 62

210. **TITLE:** Radiation Control in the Primary Coolant Loop of PWR Plants
CONTRACTORS: Babcock & Wilcox Co.
Westinghouse Electric Corp.
Combustion Engineering Inc.
Gebco Engineering
AMOUNT: 188

211. TITLE: In-Plant Demonstration of Probes for pH, Dissolved Hydrogen and Corrosion Potential
CONTRACTORS: SRI International
AMOUNT: 183

212. TITLE: Corrosion Product Dissolution
CONTRACTORS: Central Electricity Generating Board
AMOUNT: 150

213. TITLE: High-Temperature Filtration
CONTRACTORS: Atomic Energy Commission
AMOUNT: 50

214. TITLE: In-Plant Instrumentation for Corrosive Conditions
CONTRACTORS: General Electric Co.
American University
University of Arizona
AMOUNT: 362

215. TITLE: Advanced Low-Level Radwaste Treatment Systems Technology
CONTRACTORS: Sargent & Lundy Engineers
Impell Corporation
National Nuclear Corp.
Babcock & Wilcox Co.
BVC Consultants, Inc.
Paul Mayo Associates
Analytic Sciences Corp.
NWT Corporation
AMOUNT: 212

216. TITLE: Reactor System Fission Product Transport Computer Code Package
CONTRACTORS: Stanford University
AMOUNT: 10

217. TITLE: Secondary System Water Treatment Optimization
CONTRACTORS: Paul Cohen
San Diego State Univ. Foundation
Atomic Energy of Canada, Ltd.
Gibbs & Hill, Inc.
Wirth, Louis F.
Westinghouse Electric Corp.
AMOUNT: 303

218. TITLE: BWR Radiation Control-Plant Demonstration
CONTRACTORS: NWT Corporation
AMOUNT: 69

219. TITLE: Qualification of Alternate Materials for Cobalt Alloys
CONTRACTORS: Amax Materials Research Center
Consumers Power Company
Martin Marietta Energy Systems, Inc.
Westinghouse Electric Corp.
AMOUNT: 218

220. TITLE: Corrosion Product Cobalt Release Rates
CONTRACTORS: Atomic Energy of Canada, Ltd.
AMOUNT: 115

221. TITLE: Control of Cobalt Transport in LWRs
CONTRACTORS: Aere Harwell
General Electric Co.
AMOUNT: 419

222. TITLE: Decontamination Process Development and Demonstration
CONTRACTORS: Vermont Yankee Nuclear Power Corp.
Quadrex Computer Systems, Inc.
London Nuclear Services, Inc.
General Electric Co.
Commonwealth Research Corporation
AMOUNT: 430

223. TITLE: Field Test of Oxygen Control Agents
CONTRACTORS: Burns & Roe, Inc.
AMOUNT: 145

224. TITLE: Monitoring Chemical Contaminants
CONTRACTORS: Science Applications International
AMOUNT: 288

225. TITLE: Radwaste Processing
CONTRACTORS: North Carolina State University
Duke Power Company
ITT Research Institute
Babcock & Wilcox Co.
AMOUNT: 260

226. TITLE: Crud Transport Chemistry
CONTRACTORS: NWT Corporation
Advanced Process Technology
AMOUNT: 121

227. TITLE: Passivation and Surface Conditioning
CONTRACTORS: London Nuclear Services, Inc.
University of Pittsburgh
Gannon University
SRI International
AMOUNT: 158

228. TITLE: Corrosion Control Additives
CONTRACTORS: NUS Corporation
AMOUNT: 155

229. TITLE: PWR Radiation Control Demonstration
CONTRACTORS: Westinghouse Electric Corp.
AMOUNT: 73

230. TITLE: Low-Level Waste Disposal Technology
CONTRACTORS: Rogers and Associates Engineering Co.
AMOUNT: 175

231. TITLE: Waste Stabilization and Storage
CONTRACTORS: Sargent & Lundy Engineers
AMOUNT: 7

Advanced Nuclear Generation Program

232. TITLE: Fast Breeder Systems and Non-Proliferation Fuel Cycles
CONTRACTORS: International Energy Associates, Ltd.
AMOUNT: -20

233. TITLE: LWR Standardized Plant Design Evaluation
CONTRACTORS: S. Levy Inc.
Touro College
M.P.R. Associates, Inc.
Combustion Engineering Inc.
Battelle-Columbus Laboratories
Pickard, Lowe & Garrick, Inc.
AMOUNT: 306

234. TITLE: Development of Flow Coupler Electromagnetic Pump for Large LMFBRs
CONTRACTORS: Pickard, Lowe and Garrick, Inc.
AMOUNT: 103

235. TITLE: HTGR Technology Assessment and Technology Transfer
CONTRACTORS: GA Technologies, Inc.
Pickard, Lowe & Garrick, Inc.
Madell, John
Combustion Engineering Inc.
Burns & Roe, Inc.
Proto-Power Corporation
General Electric Co.
Public Service Company of Colorado
AMOUNT: 479

236. TITLE: LMFBR Commercial Size Studies
CONTRACTORS: Southern Electric International, Inc.
Amorosi, Alfred
AMOUNT: 6

237. TITLE: Technical Evaluation Tasks
CONTRACTORS: Pickard, Lowe & Garrick, Inc.
Johnson, Morris
Babcock & Wilcox Co.
Westinghouse Electric Corp.
U.S. Department of Energy
AMOUNT: 138

238. TITLE: LMFBR Technical Integration Studies
CONTRACTORS: Bechtel Group, Inc.
Burns & Roe, Inc.
General Electric Co.
Rockwell International Corp.
Stone & Webster Eng. Corp.
International Energy Associates Ltd.
Fauske & Associates, Inc.
Tecop, Inc.
Westinghouse Electric Corp.
Amorosi, Alfred
Rowan, William
Southern Electric International, Inc.
Combustion Engineering Inc.
AMOUNT: 2,135

239. **TITLE:** Advanced LWR Program
CONTRACTORS: Combustion Engineering Inc.
Westinghouse Electric Corp.
M.P.R. Associates Inc.
S. Levy Inc.
General Electric Co.
Babcock & Wilcox Co.
Stone & Webster Eng. Corp.
Massachusetts Institute of Technology
AMOUNT: 4,118

Generic Safety Analysis Program

240. **TITLE:** Application of PRA to Generic Safety Issues
CONTRACTORS: Erin Engineering & Research, Inc.
Delian Corporation
NUS Corporation
Pickard, Lowe & Garrick, Inc.
AMOUNT: 106

241. **TITLE:** Contract Research and Development and Computer Costs Related to Generic Safety Issues
CONTRACTORS: Power Computing Company
Energy Incorporated
Pickard, Lowe & Garrick, Inc.
S. Levy Inc.
Mollerus Engineering
Aptech Engineering Services, Inc.
Science Applications International
Combustion Engineering Inc.
Nuclear Projects, Inc.
Volian Enterprises
General Electric Co.
Babcock & Wilcox Co.
Horowitz, Jeffery S.
Intermountain Technologies Inc.
M.P.R. Associates Inc.
Quadrex Computer Systems, Inc.
Astron Research & Engineering
Brookhaven National Laboratory
Technology Application Inc.
AMOUNT: 1,738

OWNERS GROUPS

Steam Generator Owners Group I

1. **TITLE:** Model Test of Once Through Steam Generator for Code Verification and Lane Blocker Assessment
   CONTRACTORS:
   Consumers Power Company
   Arkansas Power & Light
   Duke Power Company
   AMOUNT: 43

2. **TITLE:** Steam Generator Technology Transfer
   CONTRACTORS:
   Gebco Engineering
   Gustafsson, Ulla
   AMOUNT: 26

Steam Generator Owners Group II

3. **TITLE:** Improved Steam Generator Nondestructive Examination Techniques
   CONTRACTORS:
   J. A. Jones Applied Research Co.
   Westinghouse Electric Corp.
   Combustion Engineering Inc.
   Babcock & Wilcox Co.
   AMOUNT: 1,186

4. **TITLE:** Arrest Steam Generator Intergranular Attack & Tube Cracking
   CONTRACTORS:
   Brookhaven National Laboratory
   Jones, Denny A.
   Combustion Engineering Inc.
   Framatome
   Lawrence Livermore Lab.
   Westinghouse Electric Corp.
   Babcock & Wilcox Co.
   Battelle-Columbus Laboratories
   Rockwell International Corp.
   University of Nevada - Reno
   NWT Corporation
   Dominion Engineering, Inc.
   Calgon Corporation
   Commissariat a L'Energie Atomique
   AMOUNT: 1,744

5. **TITLE:** Causes and Corrective Actions for Primary Water Cracking of Steam Generator Tubing
   CONTRACTORS:
   Brookhaven National Laboratory
   S. Levy Inc.
   Pennsylvania State University
   NWT Corporation
   Stone & Webster Eng. Corp.
   Dominion Engineering, Inc.
   Structural Integrity Associates
   Westinghouse Electric Corp.
   Battelle-Northwest
   Massachusetts Institute of Technology
   Studsvik Energiteknik AB
   Babcock & Wilcox Co.
   Combustion Engineering Inc.
   Foster Wheeler Energy Corporation
   Ohio State University
   Belgatom
   Cordovi, Marcel A.
   Westinghouse Electric Corp.
   AMOUNT: 1,856

6. **TITLE:** Destructive Analysis of Steam Generator Components
   CONTRACTORS:
   J. A. Jones Applied Research Co.
   Westinghouse Electric Corp.
   Battelle Memorial Institute
   NUS Corporation
   Union Electrica-Fenosa
   Northern States Power Co.
   AMOUNT: 522

7. **TITLE:** PWR Steam Generator Chemical Cleaning Process Development and Evaluation
   CONTRACTORS:
   Babcock & Wilcox Co.
   M.P.R. Associates Inc.
   Combustion Engineering Inc.
   PN Systems and Services, Inc.
   Westinghouse Electric Corp.
   Duke Power Company
   NWT Corporation
   AMOUNT: 838

8. TITLE: Evaluation and Improvement Steam Generator Performance and the Effectiveness of Preventive & Corrective Measures
CONTRACTORS: Westinghouse Electric Corp.
NWT Corporation
Radiological & Chemical Tech. Inc.
Babcock & Wilcox Co.
MUS Corporation
Sargent & Lundy Engineers
Balazs Analytical Laboratory, Inc.
AMOUNT: 303

9. TITLE: PWR Steam Generator Technology Transfer
CONTRACTORS: Torrey Pines Technology
Gebco Engineering
Energy Management Sources
AMOUNT: 298

10. TITLE: Causes and Corrective Actions for Pitting of Steam Generator Tubing
CONTRACTORS: Ohio State University
Combustion Engineering Inc.
Battelle-Columbus Laboratories
Bogaerts, Walter
AMOUNT: 291

11. TITLE: Minimize the Effects of Sludge, Scale and Deposits on Corrosion in Steam Generators
CONTRACTORS: Dominion Engineering, Inc.
Energy Management Services, Inc.
Combustion Engineering Inc.
AMOUNT: 140

12. TITLE: Tube Fretting and Wear in Preheat Steam Generators
CONTRACTORS: Combustion Engineering Inc.
Foster Wheeler Energy Corporation
Jaycor
Southwest Research Institute
Westinghouse Electric Corp.
AMOUNT: 1,300

13. TITLE: Improved Tube Support Materials and Designs
CONTRACTORS: Atomic Energy of Canada, Ltd.
NWT Corporation
Central Electricity Generating Board
Commissariat a L'Energie Atomique
Westinghouse Electric Corp.
AMOUNT: 309

Seismicity Owners Group

14. TITLE: Seismic Hazards--Seismicity Owners' Group
CONTRACTORS: Woodward-Clyde Consultants
Toksoz, M. N.
Alexander, S. S.
Hinze, William J.
Nuttli, Otto
Allen, Clarence R.
Weston Geophysical Corp.
Dames & Moore
Law Engineering Testing Company
Bechtel Group, Inc.
Rondout Associates Incorporated
Cornell, C. Allen
Zoback, Mark D.
Cynga Energy Services
Solomon, Sean
Brillinger, David
Applied Decision Analysis, Inc.
Hudson, Donald
Arabasz, Walter
Geomatrix Consultants
Risk Engineering Inc.
AMOUNT: 1,450

Nuclear Fuel Industry Research Owners Group

15. **TITLE:** Nuclear Fuel Industry Research (NFIR) Owners Group
CONTRACTORS: Commissariat a L'Energie Atomique
Atomic Energy of Canada, Ltd.
Exxon Nuclear Co., Inc.
British Nuclear Fuels, Ltd.
Belgonucleaire
C-E Power Systems
Central Electricity Generating Board
Nuclear Power Experience, Inc.
AMOUNT: 743

Hydrogen Control Owners Group

16. **TITLE:** BWR 6/Mark III-Hydrogen Control Owners Group
CONTRACTORS: Factory Mutal Res. Corp.
Fauske & Associates, Inc.
Lawrence Berkeley Lab.
Power Computing Company
AMOUNT: 1,059

Boiling Water Reactors Owners Group II

17. **TITLE:** Detection & Sizing of IGSCC in BWR Piping
CONTRACTORS: J. A. Jones Applied Research Co.
Science Applications International
Amdata Systems, Inc.
S. Levy Inc.
General Electric Co.
AMOUNT: 863

18. **TITLE:** Testing of Interim Repairs and Remedies for Cracked Piping
CONTRACTORS: General Electric Co.
Battelle-Northwest
Dunegan Corporation
AMOUNT: 1,006

19. **TITLE:** BWROG-II Technology Transfer
CONTRACTORS: Structural Integrity Associates
General Electric Co.
Steinert, Larry D.
Vaile, Robert B.
AMOUNT: 147

20. **TITLE:** Qualification of BWR Decontamination and Passivation Techniques
CONTRACTORS: General Electric Co.
AMOUNT: 224

21. **TITLE:** BWR Recirculation Piping System Replacement/Repair
CONTRACTORS: J. A. Jones Applied Research Co.
SRI International
Southwest Research Institute
Schonberg Radiation Corp.
Commonwealth Edison Company
AMOUNT: 1,919

Appendix E

Sample Questionnaire on Nuclear Safety Research

1. In your view, which of the following constitute "nuclear safety research":

    (a) research supporting the operation and maintenance of nuclear power plants

    (b) research in support of licensing

    (c) research to reevaluate existing regulations against new criteria

    (d) research on new designs

    (e) research to extend the life of existing reactors

    (f) basic research

    (g) other (please specify)

2. What safety research of this kind are you engaged in?

3. What nuclear safety research are you planning to undertake that you are not now doing?

4. How is your research divided between short- and long-term research? What is the purpose of your research?

5. In general, what safety research should be done; who should do it; who should use it; and who should fund it?

6. What safety research now being done should be brought to closure?

7. Do you believe that research responsibilities are properly allocated within the NRC? within DOE? within industry? If you do not, how might they be reallocated?

8. What are your views on the current state of cooperative government-industry research in this country?

9. How effectively, in your judgment, does this country integrate safety research done abroad? research done by U.S. industry? research done by government? research done in the universities?

10. What is your view of the quality of nuclear safety research currently being done?

11. How do you view the performance of the United States in replenishing the pool of scientific talent available for conducting research in nuclear safety?

12. To what extent does the federal government have a responsibility for sustaining the technical community engaged in nuclear safety research?

13. What constraints impinge on nuclear safety research?

14. What recommendations do you have for improving nuclear safety research?

Appendix F: Recipients of the Committee's Questionnaire

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Pickard, Lowe & Garrick
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Sr. Partner
Sargent and Lundy, Inc.

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American Electric Power Company

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Department of Chemical
Engineering
University of Maryland

Mr. T. Louis Austin
President
Brown & Root

Dr. Sanjay Banerjee
Chairman, Department of
Chemical and Nuclear Engineering
University of California - Santa
Barbara
Mr. Demetri Basdekis
Electrical Engineering and
Instrumentation
Control Branch
U.S. Nuclear Regulatory
Commission

Mr. Ken Baskin
Vice President for Nuclear
Operations
Southern California Edison

Mr. Julius W. Becton, Jr.
Director
Federal Emergency Management
Agency

Dr. A. L. Belblidia
Nuclear Research Center
Georgia Institute of Technology

Dr. Gilbert A. Bollinger
Department of Geophysics
Virginia Polytechnic Institute

Mr. Otis R. Bowen
Secretary
Department of Health & Human
Services

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Philadelphia Electric Company

Mr. Shelby Brewer
Vice President
Combustion Engineering

Mr. Dale Bridenbaugh
MHB Associates
San Jose, California

Dr. Harvey Brooks
Aiken Computation Lab
Harvard University

Dr. Ken Buchert
School of Engineering
University of Southern Illinois

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Consumers Power Company

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Arkansas Power and Light

Mr. Jack Carey
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LeHigh University

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Ebasco Services, Inc.

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University of Wisconsin

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Corporation

Mr. Jim Cleveland
SEA, Inc.
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Georgia Power Company

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Dr. M. L. Corradini
Department of Nuclear Engineering
University of Wisconsin

Dr. Jaak K. Daemen
Department of Geological
Engineering
University of Arizona

Mr. Edward M. Davis
President
American Nuclear Energy Council

Mr. W. Kenneth Davis
Consultant
San Francisco, California

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Office of the Provost
Massachusetts Institute of
Technology

Mr. John DeVincentis
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Seabrook, New Hampshire

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Secretary
Department of Transportation

Mr. J. L. Dooley
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Public Service of Colorado

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G.P.U. Nuclear Corporation

Mr. Roger Kober
Vice President for Electricity and Steam Production
Rochester Gas & Electric

Mr. Glenn Koester
Vice President for Nuclear Power
Kansas Gas and Electric

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University of Delaware

Mr. Larry Kunc
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Nebraska Public Power District

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Mr. William S. Lee
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Mr. Thomas Lempges
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Niagara Mohawk Power Company

Mr. John D. Leonard
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Shoreham Nuclear Power Station

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Massachusetts Institute of Technology

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Sal Levy, Inc.
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Mr. George Maneatis
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Mr. Jerry Martin
Washington Public Power Supply System

Mr. Robert Patrick McDonald
Chief of Nuclear Power Generation
Alabama Power Company

Mr. M. A. McDuffie,
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Carolina Power & Light

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Mr. Philip Pymon
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Nuclear Information Resource Service

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Notheast Utilities

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Pacific Gas & Electric

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Columbia University

Mr. Warren K. Sinclair
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National Council on Radiation
Protection and Measurement

Mr. Madan M. Singh
President
Engineering International, Inc.

Dr. David B. Slemmons
Departemnt of Geology &
Geophysics
University of Nevada

Dr. Mete Sozen
Department of Civil Engineering
University of Illinois

Mr. Hunter Spillan
House Committee on
Appropriations

Dr. Chauncey Starr
Vice Chairman
Electric Power Research Institute

Mr. William L. Stewart
Vice President for Nuclear
Operations
Virginia Power Company

Dr. Pradeep Talwani
Department of Geology
University of South Carolina

Dr. Theo C. Theofanous
Department of Chemical and
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Barbara

Mr. George F. Thomas
Vice President for Production
New Hampshire Yankee Division
Public Service Company of New
Hampshire

Mr. Lee M. Thomas
Administrator
Environmental Protection Agency

Dr. Clifford H. Thurber
Department of Earth Sciences
State University of New York -
Stonybrook

Mr. Joseph Tiernan
Sr. Vice President for Nuclear
Power
Baltimore Gas & Electric

Dr. Neil Todreas
Department of Nuclear Engineering
Massachusetts Institute of
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Dr. Nafi Toksoz
Department of Earth, Atmospheric
and Planetary Sciences
Massachusetts Institute of
Technology

Mr. Hal Tucker
Chairman
B&W Owners Group

Dr. Robert Uhrig
Department of Nuclear Engineering
University of Tennessee

Mr. Edward Uthe
SRI International

Mr. Edwin Van Brunt
Vice President for Nuclear Power
Arizona Public Service Company

Mr. Carl Walske
Atomic Industrial Forum

Mr. John Ward
President
Radiation Research Society

Dr. Alvin M. Weinberg
Institute for Energy Analysis

Mr. Abraham Weitsberg
NUS Corporation
Gaithersburg, Maryland

Mr. Rik Wells
Chairman
Combustion Engineering Owners
Group

Mr. Steven White
Manager, Nuclear Power
Tennessee Valley Authority

Mr. Walter S. Wilgus
Vice President for Nuclear Power
Florida Power Corporation

Admiral Joe Williams
Sr. Vice President for Nuclear Power
Toledo Edison

Mr. Bart Withers
Vice President for Nuclear Power
Portland General Electric

Mr. C. O. Woody
Group Vice President-Nuclear
Florida Power & Light

Mr. Isa Yin
Engineering Branch
Division of Reactor Safety
U.S. Nuclear Regulatory Commission

Dr. Al L. Young
Commission on Interagency Radiation Research and Policy Coordination
Executive Office of the President

Dr. Walter H. Zinn
Clearwater, Florida

Appendix G: Participants in Committee Hearings

1. ***November 21-22, 1985***
   Robert Budnitz, Future Resources Associates, Inc.
   Delbert Bunch, U.S. Department of Energy
   Herbert Kouts, Brookhaven National Laboratory
   Robert Minogue, U.S. Nuclear Regulatory Commission
   Nunzio J. Palladino, U.S. Nuclear Regulatory Commission

2. ***February 6-7, 1986***
   Randy Carter, B&W Alliance Research Center
   William Dircks, Atomic Industrial Forum
   David McGoff, U.S. Department of Energy
   Warren Minners, U.S. Nuclear Regulatory Commission
   Paul North, EG&G Idaho National Engineering Laboratory
   Bernard Rock, U.S. Department of Energy
   Bill Snyder, Sandia National Laboratory
   Themis Speis, U.S. Nuclear Regulatory Commission
   Michael Stevenson, Los Alamos National Laboratory
   Ed Wood, General Electric Co.
   Larry Ybarrondo, Ybarrondo & Associates, Inc.

3. ***April 3-4, 1986***
   Guy Arlotto, U.S. Nuclear Regulatory Commission
   James K. Asselstine, U.S. Nuclear Regulatory Commission
   Frederick Bernthal, U.S. Nuclear Regulatory Commission
   Gary Burdick, U.S. Nuclear Regulatory Commission
   Sol Burstein, Wisconsin Electric Power Co.
   Donald Edwards, Yankee Atomic Power Co.

Jim Gallagher, Westinghouse Electric Corp.
Dick Gardner, Stone & Webster Engineering Corp.
Frank Gillespie, U.S. Nuclear Regulatory Commission
Karl Goller, U.S. Nuclear Regulatory Commission
Walt Loewenstein, Electric Power Research Institute
Bill Morris, U.S. Nuclear Regulatory Commission
Cordell Reed, Commonwealth Edison Co.
Steve Rosen, Institute of Nuclear Power Operations
Herschel Specter, New York Power Authority
Terry Sullivan, Institute of Nuclear Power Operations
Bert Wolfe, General Electric
Lando W. Zech, Jr., U.S. Nuclear Regulatory Commission

4. *May 15-16, 1986*
Del Bunch, U.S. Department of Energy
Ivan Catton, U.C.L.A.
Jerry Griffith, U.S. Department of Energy
Mark Kerrigan, Office of Management and Budget
Richard T. Lahey, Jr., Rensselear Polytechnic Institute
Honorable James A. McClure, United States Senate
Robert Minogue, U.S. Nuclear Regulatory Commission
Thomas Palmieri, Office of Management and Budget
Denwood Ross, U.S. Nuclear Regulatory Commission
Chester Seiss, Advisory Committee on Reactor Safeguards
Victor Stello, U.S. Nuclear Regulatory Commission
Theofanis Theofanous, U.C. - Santa Barbara
David A. Ward, Advisory Committee on Reactor Safeguards

Appendix H
Biographical Sketches of the Members

ROBERT A. FROSCH **(Chairman)**

Bob Frosch is vice president in charge of research laboratories at General Motors Corporation, a member of the National Academy of Engineering, and former chairman of the National Research Council's Naval Studies Board. He is a former administrator of the National Aeronautics and Space Administration (NASA), a former assistant secretary of the Navy for research and development, and a former director of Hudson Laboratories at Columbia University. He is the recipient of a number of awards, including the Industrial Research Institute's Maurice Holland Award and NASA's Distinguished Service Medal.

JOHN F. AHEARNE

John Ahearne is vice president of Resources for the Future. He is a former commissioner of the Nuclear Regulatory Commission and served as chairman from December 1979 to March 1981. Dr. Ahearne previously served in a number of posts in the Defense Department, including director of tactical air programs, deputy assistant secretary of defense for program analysis and evaluation, and principal deputy assistant secretary of defense for manpower and reserve affairs.

ROBERT AVERY

Bob Avery is a senior physicist at Argonne National Laboratory. He has been director of Argonne's Reactor Analysis and Safety Division and, before that, of the Applied Physics Division. He is a member of the National Academy of Engineering. Dr.

Avery is an expert in nuclear reactor safety and was the chairman of a special committee of the American Nuclear Society on safety goals for nuclear powerplants.

JAMES BILODEAU

Jim Bilodeau is an associate engineer working with Eagle Engineering. From 1971 to 1974, he was chief of the National Aeronautics and Space Administration's Crew Procedures Division, where he supervised the development of rules and procedures for the conduct of manned space missions. He served as a member of the Crew Safety Panel on both the Gemini and Apollo programs. He later served as chief of NASA's Crew Training and Procedures Division, where he was given the added responsibility of managing the training programs for astronauts and flight control personnel in the Shuttle Program.

ROBERT S. BRODSKY

Bob Brodsky is a principal managing partner of Basic Energy Technology Associates, Inc., a consulting firm serving clients in the nuclear industry and at all levels of government. He has over 25 years of experience in the naval nuclear program and served as one of Admiral Rickover's principal aides on matters relating to reactor safety. As assistant director for reactor safety and computation in the Naval Reactors Division at the Department of Energy, he was responsible for design and operational safety of the Navy's shipboard nuclear propulsion plants, the Department of Energy's naval nuclear prototypes, and the Shippingport Atomic Power Plant.

ANNICK CARNINO

Annick Carnino is a nuclear engineer who serves as assistant to the director of the Inspector General for the Safety and Security of Nuclear Installations, Electricite de France. From 1963 to 1982 she worked for the French Atomic Energy Commission, where her main fields of interest were neutronics, thermal-hydraulic calculations, and reactor safety. From 1972 to 1980, she was also head of the Probabilistic Safety Assessment Group in the Institute for Nuclear Safety and Radiological Protection. She is a member of the American, British and French nuclear societies and a recipient of the Chevalier de l'Ordre National du Merite.

MYRON B. FIERING

Mike Fiering is Gordon McKay Professor of Engineering and Applied Mathematics at Harvard University. He is an expert in the integration of error estimation in large scale hydrodynamic modeling, and in water resource and other environmental engineering problems. Prior to taking up his current post at Harvard, he was assistant professor of engineering at the University of California at Los Angeles and a Fulbright lecturer and visiting associate professor of engineering at the University of New South Wales, Australia.

TED GREENWOOD

Ted Greenwood is associate professor of political science at Columbia University and affiliated with the Institute of War and Peace Studies. From 1974 through 1984 he was on the faculty of the political science department at M.I.T., where he taught science, technology and public policy and national security and arms control. During the Carter administration he served as a senior policy analyst in the Office of Science and Technology Policy, where his responsibilities included concern for the federal nuclear research and development program. Dr. Greenwood was a member of the National Research Council's Committee on Institutional Means for the Assessment of Risk to Public Health. He has written extensively on federal policy toward radioactive waste disposal and other aspects of nuclear policy and on governmental decisionmaking in public policy arenas with important science and technology components.

WILLIAM E. KASTENBERG

Bill Kastenberg is professor of engineering and applied science and chairman of the Department of Mechanical, Aerospace and Nuclear Engineering at the University of California at Los Angeles. He is an expert in nuclear reactor physics, reactor dynamics, risk assessment and nuclear safety and has served as a consultant to a number of governmental agencies. From 1979 to 1980 he was a senior fellow of the Advisory Committee on Reactor Safeguards of the U.S. Nuclear Regulatory Commission. Dr. Kastenberg is the past chairman of the American Nuclear Society's Nuclear Reactor Safety Division.

HUGH KENDRICK

Hugh Kendrick is a professional nuclear engineer who is deputy chief operating officer at Science Applications International Corporation, where he is responsible for the direction of the firm's research and development program. Formerly he was acting director of the Office of Plans and Analysis in the Office of the Assistant Secretary for Nuclear Reactor Programs at the Department of Energy.

DANIEL MENELEY

Dan Meneley is professor of nuclear engineering at the University of New Brunswick. From 1983 to 1984, he was a member of a special committee of the International Nuclear Societies Group, set up to consider formation of an International Commission on Nuclear Safety. That activity led to the establishment of the International Atomic Energy Agency (IAEA) International Nuclear Safety Advisory Group, of which he is a member. From 1980 to 1984 he was manager of the Nuclear Design Group of Ontario Hydro, Canada's largest electric utility. This Group is responsible for safety systems design and licensing, mechanical design of NSSS systems, and waste management. He was previously manager of the Nuclear Studies and Safety Department. He gained nine years of experience at Argonne National Laboratory, where he held the post of chief of the Reactor Analysis Section. He is a member of the Board of Directors of the American Nuclear Society.

ANTHONY ROISMAN

Tony Roisman is the executive director of Trial Lawyers for Public Justice. He has extensive experience with the Nuclear Regulatory Commission's licensing and appeals process and was a member of the Nuclear Regulatory Commission's Ad Hoc Committee for Review of Nuclear Reactor Licensing Proposals. He is also a member of the NRC's Advisory Panel on Atomic Safety and Licensing Board Nominating. He was the first chief of the Department of Justice's Hazardous Waste Section, and is chairman of the Subcommittee on Victim Compensation of the Committee on Health and Environmental Law of the American Bar Association.

CHRIS G. WHIPPLE

Chris Whipple is technical manager of the Electric Power Research Institute's Energy Study Center, and a member of the National Research Council's Board on Radioactive Waste Management. He previously served on an Academy committee on the health and environmental impacts of the synthetic fuels industry. Dr. Whipple is an expert on technological risk assessment and a former president of the Society for Risk Analysis. He has chaired two IAEA research coordinating meetings on risk criteria for the nuclear fuel cycle. He has been a member of three National Science Foundation advisory committees for projects on risk assessment.

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ROBERT J. BUDNITZ

Bob Budnitz is president of Future Resources Associates, Inc., a consulting firm. He is a former director of the Nuclear Regulatory Commission's Office of Research, and previously served on the "Lewis Committee," a special review group established by the Nuclear Regulatory Commission to evaluate the Reactor Safety Study. More recently he served as a consultant to the American Physical Society's study group on radioactive source terms. Prior to joining the NRC, Mr. Budnitz was a senior staff scientist and division head of the Energy and Environment Division at Lawrence Berkeley Laboratory. He has served on several Academy panels and committees and during the course of this study he was a member of the National Research Council's Energy Engineering Board (EEB). He joined in the activity of the Committee on Nuclear Safety Research as liaison from the EEB.